

### 3. SUMMARY OF WESTERN NORTH PACIFIC AND NORTH INDIAN OCEAN TROPICAL CYCLONES

#### 3.1 GENERAL

For the western North Pacific, 1992 was another record-breaking year for the number of warnings issued — 941 (106 more than last year) on 33 tropical cyclones (Table 3-1). This was two more tropical cyclones than the long-term annual mean of 31 (Table 3-2). As in the previous two years, one additional significant tropical cyclone, Ekeka (01C), moved westward across the central North Pacific into JTWC's area of responsibility and was included in the totals. A chronology of the tropical cyclone activity is provided in Figure 3-1. Table 3-3 includes: a climatology of typhoons, tropical storms and typhoons for the period from 1945 to 1959 and 1960 to 1992; and a summary of warning days. JTWC was in warning status 159 days during 1992 compared to 169 in 1991. Although there were less total warning days, an increase in the number of multiple storm days resulted in a greater total number of warnings — 941 compared to 835 the previous year. Of these warnings, 73 were issued by AJTWC when JTWC was incapacitated for 11 days after the destructive passage of Typhoon Omar over Guam. There were 75 warning days for two or more tropical cyclones, 28 days with at least three, and 5 days with four tropical cyclones occurring simultaneously. Thirty-six initial

Tropical Cyclone Formation Alerts were issued on western North Pacific tropical disturbances (Table 3-4). Except for one initial alert that did not develop, alerts preceded warnings on all significant tropical cyclones in the western North Pacific with the exception of Typhoon Gary (07W) and Tropical Storm Val (20W).

For the North Indian Ocean, it was an extremely active year with 13 tropical cyclones which is 7 more than the annual mean of five. Four of these occurred in the Arabian Sea and nine, including Forrest (30W), in the Bay of Bengal. These tropical cyclones required a total of 190 warnings and JTWC was in warning status 48 days during 1992 compared to nine in 1991. Alerts preceded all warnings in the North Indian Ocean.

During the year, a total of 1131 warnings were issued for 45 tropical cyclones in the Northern Hemisphere. When the North Indian Ocean was included with the western North Pacific in the total, there were 182 days with warnings on one cyclone and 90 days with two or more, 41 days with three or more and 9 days with four cyclones occurring at once. There were no days in the Northern Hemisphere when warnings were issued for five or more tropical cyclones at once.

TABLE 3-1

## WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 1992

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS KT (M/SEC)	ESTIMATED MSLP (MB)
(01W) TY AXEL	05 JAN - 15 JAN	38	70 (36)	972
(01C) TS EKEKA	05 FEB - 08 FEB	19	45 (23)	991
(02W) TY BOBBIE	23 JUN - 30 JUN	27	120 (62)	922
(03W) TY CHUCK	25 JUN - 30 JUN	22	80 (41)	964
(04W) TS DEANNA	26 JUN - 03 JUL	24	40 (21)	994
(05W) TY ELI	09 JUN - 14 JUN	18	75 (39)	968
(06W) TS FAYE	16 JUL - 18 JUL	11	55 (28)	984
(07W) TY GARY	19 JUL - 23 JUL	19	65 (33)	976
(08W) TS HELEN	26 JUL - 28 JUL	9	45 (23)	991
(09W) TY IRVING	01 AUG - 05 AUG	17	80 (41)	975
(10W) TY JANIS	03 AUG - 09 AUG	27	115 (59)	927
(11W) STY KENT	05 AUG - 20 AUG	58	130 (67)	910
(12W) TS LOIS	15 AUG - 22 AUG	28	40 (21)	994
(13W) TS MARK	15 AUG - 21 AUG	21	50 (26)	987
(14W) TS NINA	18 AUG - 21 AUG	13	45 (23)	991
(15W) STY OMAR	24 AUG - 05 SEP	50	130 (67)	910
(16W) TS POLLY	25 AUG - 30 AUG	21	50 (26)	987
(17W) TY RYAN	01 SEP - 11 SEP	43	115 (59)	927
(18W) TY SIBYL	07 SEP - 15 SEP	32	110 (57)	933
(19W) TY TED	18 SEP - 24 SEP	27	65 (33)	976
(20W) TS VAL	23 SEP - 27 SEP	15	55 (28)	984
(21W) TY WARD	26 SEP - 06 OCT	40	95 (49)	949
(22W) TS ZACK	07 OCT - 15 OCT	27	40 (21)	993
(23W) STY YVETTE	08 OCT - 17 OCT	40	155 (80)	878
(24W) TY ANGELA	16 OCT - 29 OCT	41	90 (46)	954
(25W) TY BRIAN	17 OCT - 25 OCT	33	95 (49)	949
(26W) TY COLLEEN	18 OCT - 28 OCT	44	80 (41)	963
(27W) TY DAN	24 OCT - 03 NOV	40	110 (57)	927
(28W) STY ELSIE	29 OCT - 07 NOV	36	145 (75)	892
(29W) TD 29W	01 NOV - 02 NOV	3	25 (13)	1002
(30W) TS FORREST	12 NOV - 15 NOV	12	55 (28)	984
(31W) STY GAY	14 NOV - 30 NOV	63	160 (82)	872
(32W) TY HUNT	16 NOV - 21 NOV	23	125 (64)	916

TOTAL: 941

TABLE 3-2

## WESTERN NORTH PACIFIC TROPICAL CYCLONE DISTRIBUTION

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	000	010	010	100	000	001	111	512	423	210	200	200	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	001	000	001	100	010	210	210	810	041	400	100	100	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	010	010	100	010	211	114	320	313	510	322	101	100	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	000	010	000	100	201	000	512	701	313	311	301	020	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	000	000	001	100	000	310	311	301	220	510	000	210	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	000	000	000	000	201	200	611	350	521	331	420	101	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	110	020	010	100	101	310	411	322	531	201	110	010	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	000	000	000	100	200	100	310	531	532	112	122	101	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	010	000	110	100	010	100	332	343	530	211	400	010	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	000	001	000	100	000	202	120	341	400	510	400	000	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	100	000	010	100	000	000	210	210	204	410	110	010	13 6 4

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YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	000	100	000	000	000	110	021	421	220	321	130	000	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	010	000	010	200	230	200	620	311	511	310	110	000	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	100	000	001	000	000	220	410	320	411	410	200	210	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23
	000	000	000	000	000	000	430	231	201	400	030	000	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	010	000	010	010	100	121	230	232	320	400	220	020	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	100	000	000	001	000	000	010	411	410	321	210	002	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	100	010	000	110	200	200	220	130	410	000	110	020	14 11 0
1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	521	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
1987	1	0	0	1	0	2	4	4	7	2	3	1	25
	100	000	000	010	000	110	400	310	511	200	120	100	18 6 1
1988	1	0	0	0	1	3	2	5	8	4	2	1	27
	100	000	000	000	100	111	110	230	260	400	200	010	14 12 1
1989	1	0	0	1	2	2	6	8	4	6	3	2	35
	010	000	000	100	200	110	231	332	220	600	300	101	21 10 4
1990	1	0	0	1	2	4	4	5	5	5	4	1	31
	100	000	000	010	110	211	220	500	410	230	310	100	21 9 1
1991	0	0	2	1	1	1	4	8	6	3	6	0	32
	000	000	110	010	100	100	400	332	420	300	330	000	20 10 2
1992	1	1	0	0	0	3	4	8	5	6	5	0	33
	100	010	000	000	000	210	220	440	410	510	311	000	21 11 1

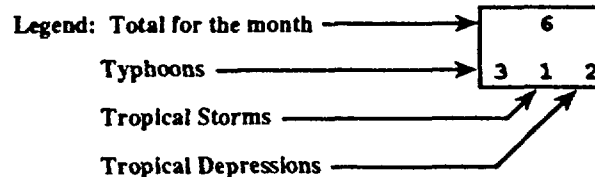
(1959-1992)

MEAN: 0.6 0.3 0.6 0.8 1.2 2.2 4.5 6.3 5.7 4.6 3.0 1.4 30.9  
 CASES: 20 10 20 25 42 73 151 214 192 156 101 46 1049

The criteria used in Table 3-2 are as follows:

1. If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.
2. If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.
3. If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 3-2 LEGEND



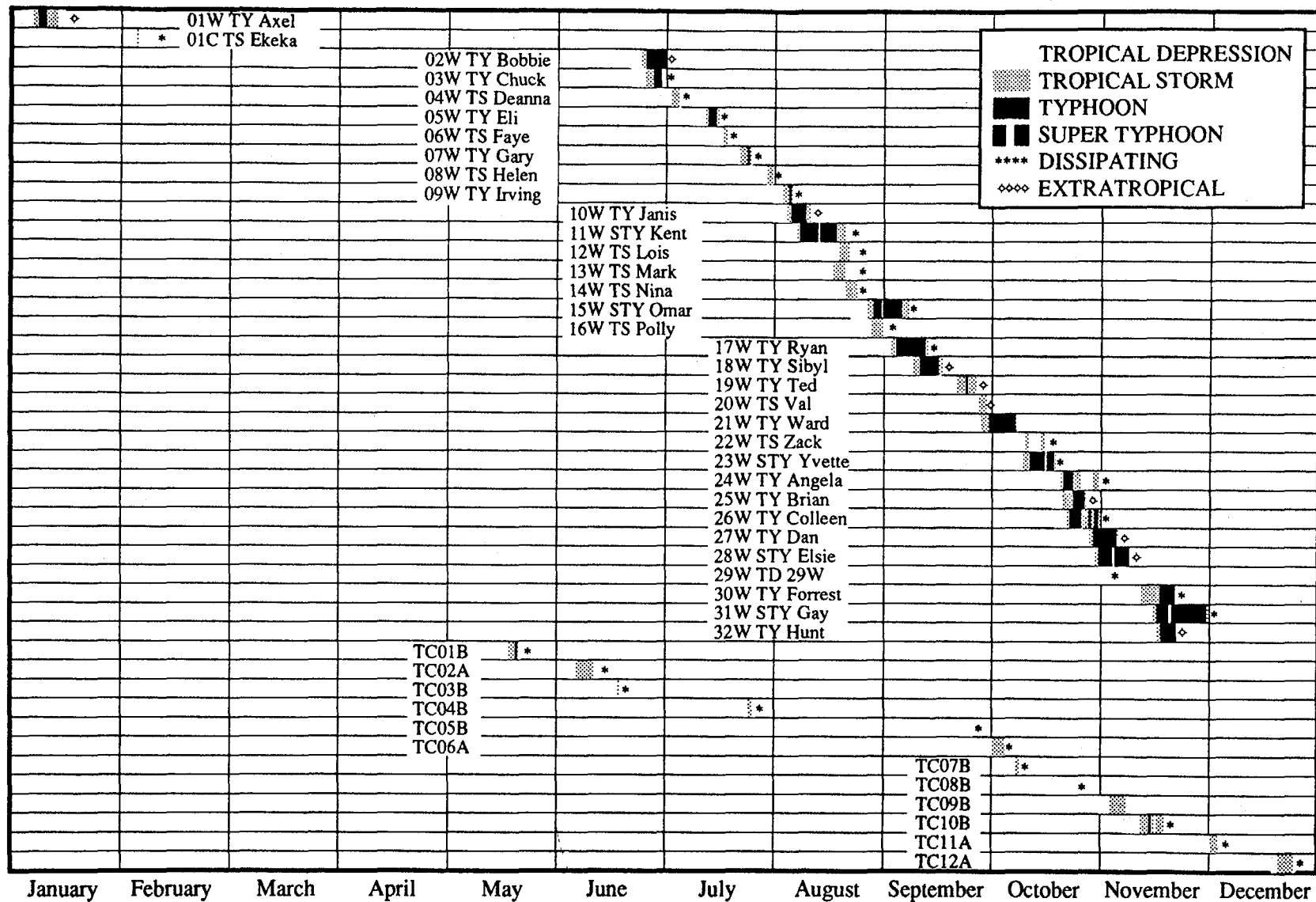


Figure 3-1. Chronology of western North Pacific and North Indian Ocean tropical cyclones for 1992.



TABLE 3-3

## WESTERN NORTH PACIFIC TROPICAL CYCLONES

## TYPHOONS

(1945 - 1959)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN:	0.3	0.1	0.3	0.4	0.7	1.0	2.9	3.1	3.3	2.4	2.0	0.9	16.4
CASES:	5	1	4	6	10	15	29	46	49	36	30	14	245

(1960 - 1992)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN:	0.3	0.1	0.2	0.5	0.7	1.1	2.7	3.2	3.3	3.2	1.8	0.6	17.7
CASES:	10	2	7	15	24	37	90	106	108	105	60	20	584

## TROPICAL STORMS AND TYPHOONS

(1945 - 1959)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN:	0.4	0.1	0.5	0.5	0.8	1.6	2.9	4.0	4.2	3.3	2.7	1.2	22.2
CASES:	6	2	7	8	11	22	44	60	64	49	41	18	332

(1960 - 1992)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN:	0.6	0.3	0.5	0.7	1.1	1.9	4.2	5.4	5.0	4.2	2.8	1.2	27.6
CASES:	19	9	15	22	36	62	137	179	164	139	92	38	912

NUMBER OF CALENDAR WARNING DAYS: 159

NUMBER OF CALENDAR WARNING DAYS WITH TWO TROPICAL CYCLONES: 47

NUMBER OF CALENDAR WARNING DAYS WITH THREE TROPICAL CYCLONES: 23

NUMBER OF CALENDAR WARNING DAYS WITH FOUR TROPICAL CYCLONES: 5

TABLE 3-4

## TROPICAL CYCLONE FORMATION ALERTS FOR THE WESTERN NORTH PACIFIC OCEAN

YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	FALSE ALARM RATE	PROBABILITY OF DETECTION
1976	34	25	25	26%	100%
1977	26	20	21	23%	95%
1978	32	27	32	16%	84%
1979	27	23	28	15%	82%
1980	37	28	28	24%	100%
1981	29	28	29	3%	96%
1982	36	26	28	28%	93%
1983	31	25	25	19%	100%
1984	37	30	30	19%	100%
1985	39	26	27	33%	96%
1986	38	27	27	29%	100%
1987	31	24	25	23%	96%
1988	33	26	27	21%	96%
1989	51	32	35	37%	91%
1990	33	30	31	9%	97%
1991	37	29	31	22%	94%
1992	36	32	32	20%	100%
(1976-1992)					
MEAN:	34.5	26.9	28.2	22%	95%
TOTALS:	587	458	481		

1992 FORMATION ALERTS: 32 OF 34 INITIAL FORMATION ALERTS DEVELOPED INTO SIGNIFICANT TROPICAL CYCLONES.

### 3.2 WESTERN NORTH PACIFIC TROPICAL CYCLONES

The year of 1992 included five super typhoons, 16 lesser typhoons, 11 tropical storms and one tropical depression. All tropical cyclones with the exception of Helen (08W), which was Tropical Upper Tropospheric Trough (TUTT)-induced, originated in the low-level monsoon trough or near-equatorial trough.

Due to warm sea-surface temperature anomalies in the central equatorial Pacific Ocean, January was a month with westerly low-level wind anomalies that extended from New Guinea eastward into the Central Pacific Ocean (Bureau of Met., 1992). These anomalies aided the development of Axel (01W) in the western North Pacific and a twin tropical cyclone in the Southern Hemisphere, and in late January, the formation of Ekeka (01C), a rare January Hurricane, south of the Hawaiian Islands. After Ekeka, there was a four month break in significant tropical cyclone activity. By mid-June the monsoon trough became established in its normal location across the South China Sea, central Philippine Islands and eastward into the Caroline Islands, and supported the formation of Bobbie (02W), Chuck (03W) and Deanna (04W) in late June (Figure 3-2).

After Deanna recurved on 2 July, the ridging and associated high pressure temporarily built into low latitudes in the Philippine Sea and replaced the monsoon trough. However, low-level southwesterly flow and weak troughing persisted to the east and supported the formation of Eli (05W) the second week of July, followed by Faye (06W), and Gary (07W) (Figure 3-3). After Gary, no significant tropical cyclones originated in the low-level monsoon trough until the end of July. In the interim, Helen (08W), which was a TUTT-induced low-level

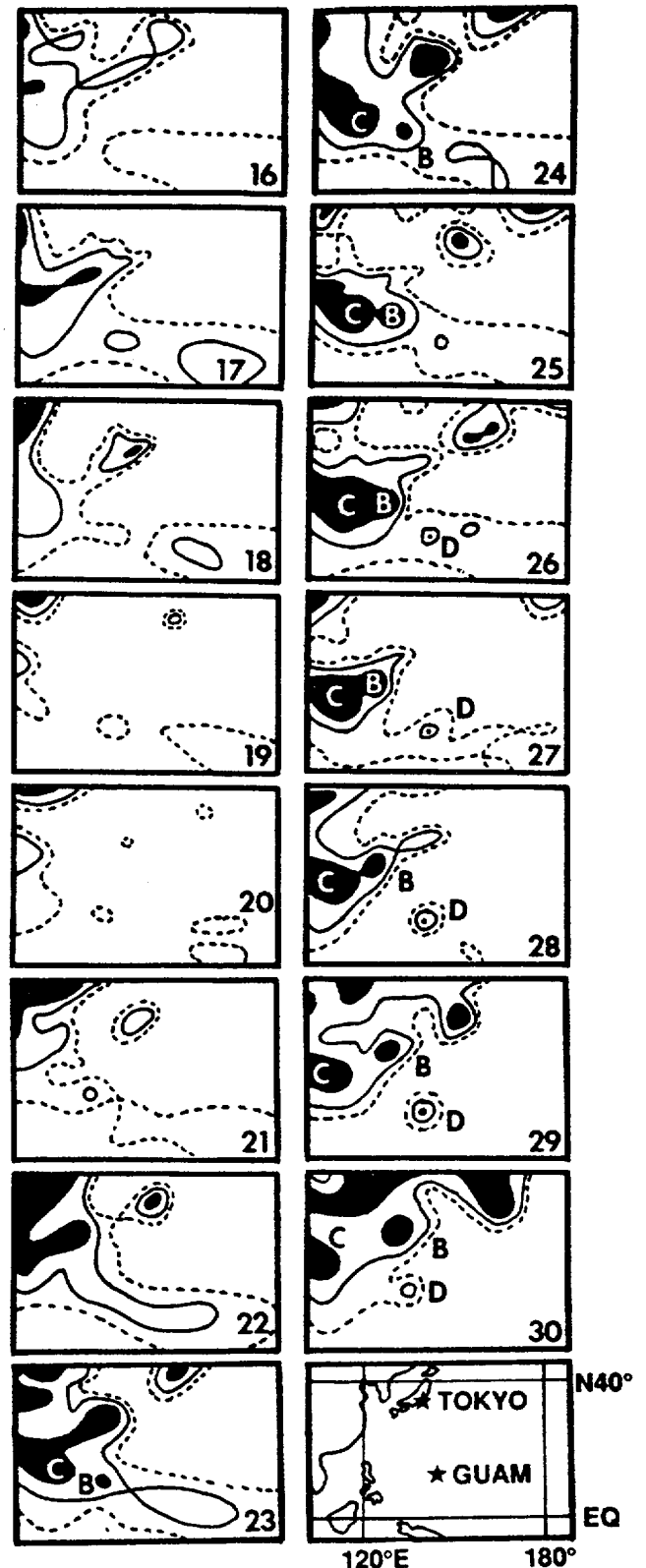


Figure 3-2. Western North Pacific sea-level pressure analyses for 16 to 30 June 1992. Map panels are for 0000Z for the date indicated in the lower right of each panel. A geographical reference appears as the lower right panel. Contours: outer dashed line = 1010 mb; solid line = 1008 mb; and, black area  $\leq 1004$  mb. Tropical cyclones: B = Bobbie (02W); C = Chuck (03W); and, D = Deanna (04W). (Analyses courtesy of M.A. Lander.)

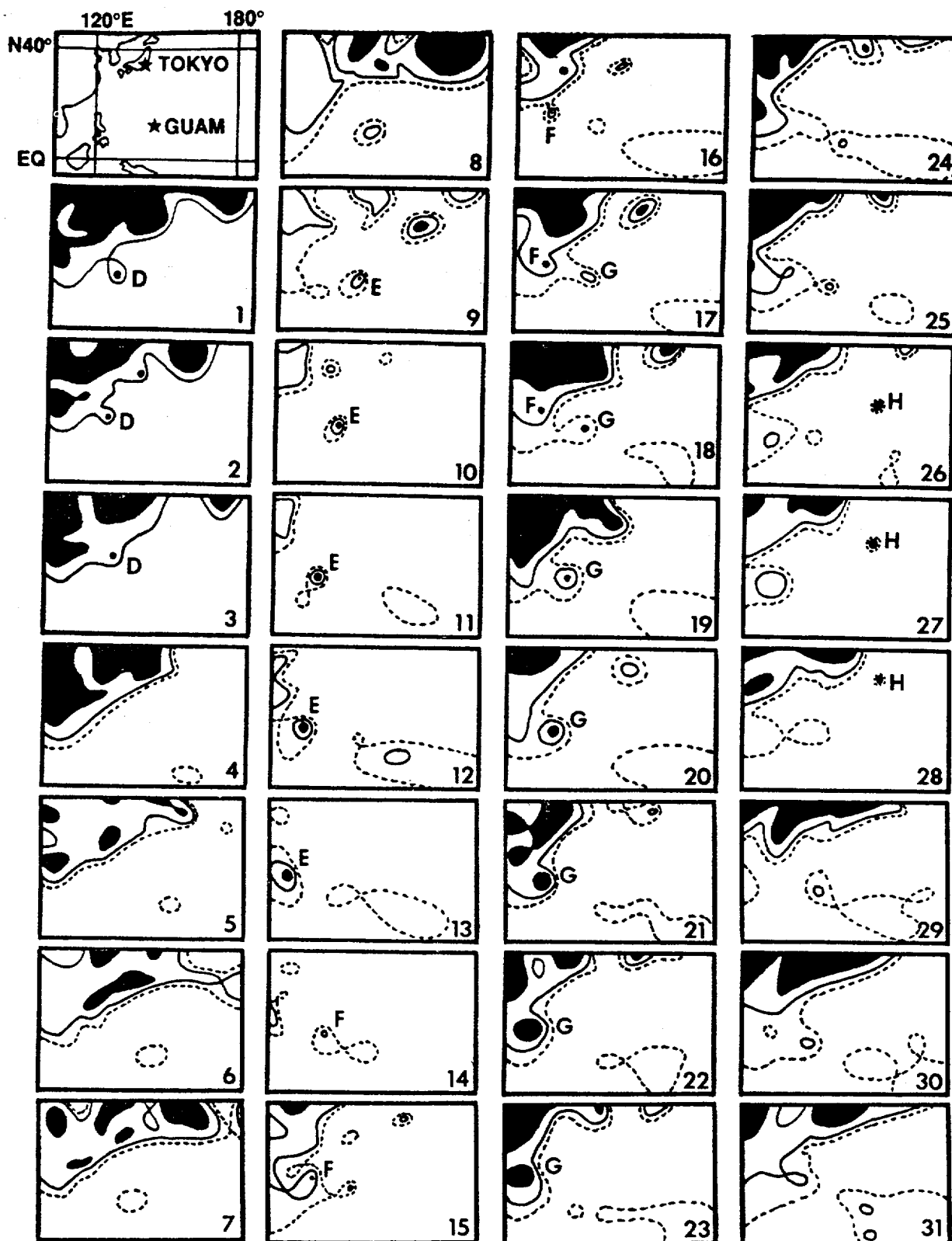


Figure 3-3. Western North Pacific sea-level pressure analyses for July 1992. Map panels are for 0000Z for the date indicated in the lower right of each panel. A geographical reference appears in the upper left panel. Contours: outer dashed line = 1010 mb; solid line = 1008 mb; and, black area  $\leq 1004$  mb. Tropical cyclones: D = Deanna (04W); E = Eli (05W); F = Faye (06W); G = Gary (07W); and, H = Helen (08W). (Analyses courtesy of M.A. Lander.)

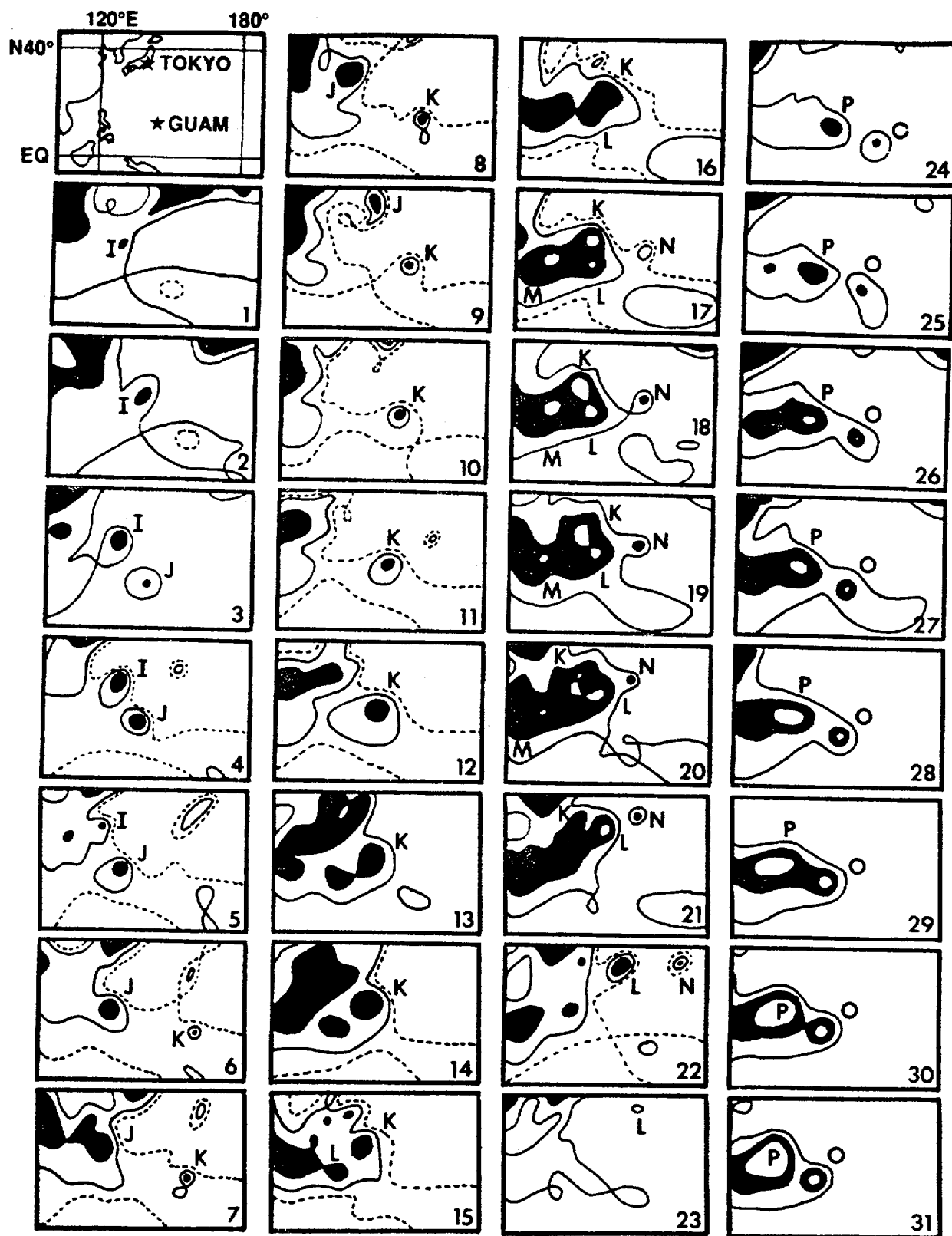


Figure 3-4. Western North Pacific sea-level pressure analyses for August 1992. Map panels are for 0000Z for the date indicated in the lower right of each panel. A geographical reference appears in the upper left panel. Contours: outer dashed line = 1010 mb; solid line = 1008 mb; black area  $\leq 1004$  mb; and, inner white area  $\leq 1000$  mb. Tropical cyclones: I = Irving (09W); J = Janis (10W); K = Kent (11W); L = Lois (12W); M = Mark (13W); N = Nina (14W); O = Omar (15W); and, P = Polly (16W). (Analyses courtesy of M.A. Lander.)

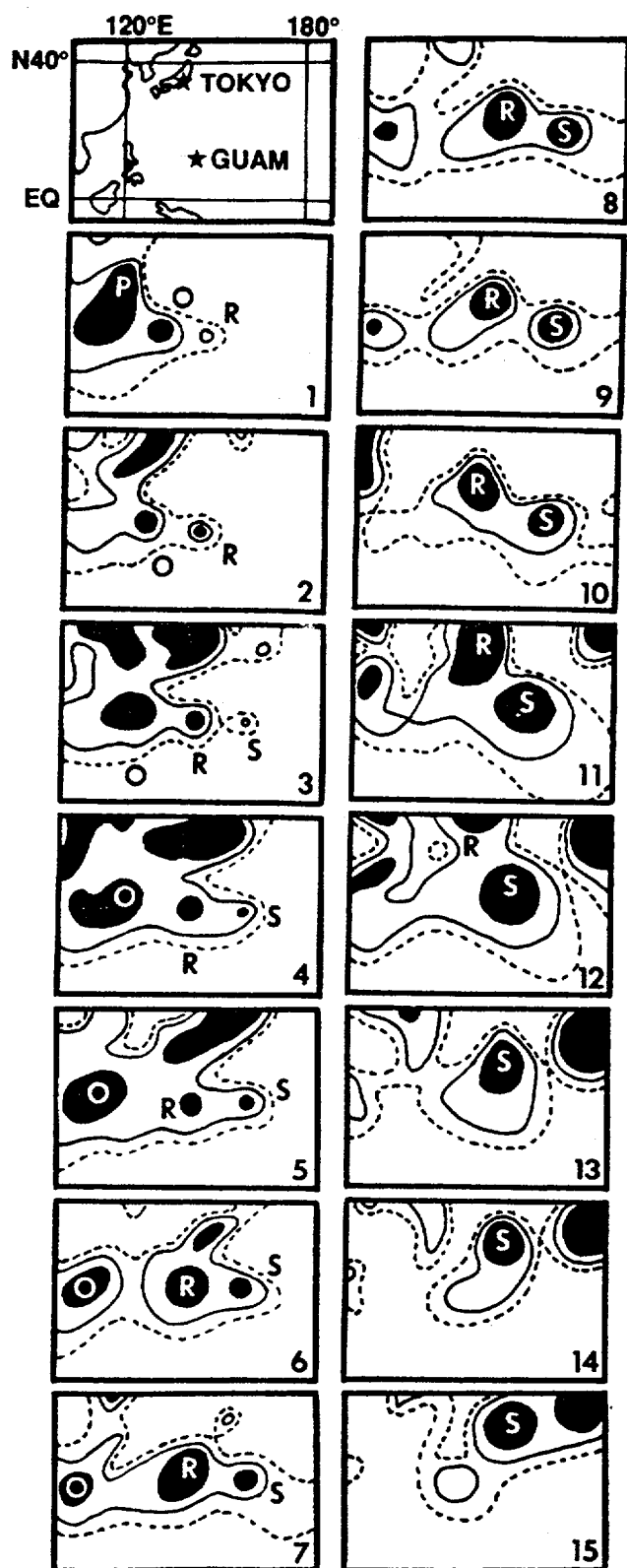


Figure 3-5. Western North Pacific sea-level pressure analyses for 1 to 15 September 1992. Map panels are for 0000Z for the date indicated in the lower right of each panel. A geographical reference appears as the upper left panel. Contours: outer dashed line = 1010 mb; solid line = 1008 mb; and, black area  $\leq 1004$  mb. Tropical cyclones: O = Omar (15W); P = Polly (16W); R = Ryan (17W); and, S = Sibyl (18W). (Analyses courtesy of M.A. Lander.)

circulation, formed on 24 July at 25° north latitude in an area of relatively high surface pressure and later recurved.

After Irving's (09W) formation on 30 July in the northern Philippine Sea and its subsequent north-oriented track, the axis of the subtropical ridge shifted slowly northward. This was reflected in the higher latitudes of recurvature for Janis (10W) and later, Kent (11W). As Kent intensified, surface pressures dropped across eastern Asia and the Philippine Sea, supporting the multiple storm outbreak which included Lois (12W), Mark (13W) and Nina (14W) (Figure 3-4).

With the demise of Lois and Nina, a major readjustment of the synoptic pattern took place at the end of the third week of August. The orientation of the axis of the monsoon trough, which was southwest-northeast, returned to its more normal northwest-southeast orientation, but extended much farther east than normal. This led to the development of Omar (15W) in the Marshall Islands and Polly (16W) just to the west of Guam. As Omar and Polly tracked west-northwestward along the axis of the trough, Ryan (17W) formed to the southeast in their wake. In its early development, Ryan tracked to the west-northwest for four days before making an abrupt course change to the north. During the first week of September, Sibyl (18W) formed at the eastern end of the low-level trough extending eastward from Omar through Ryan to Sibyl (Figure 3-5). Ryan continued northward on a north-oriented track into the Sea of Okhotsk. Following Sibyl's recurvature, there was a short break before Ted (19W) formed in the monsoon trough which had reestablished at lower latitudes. The development of Val (20W), Ward (21W), Zack (22W) and Yvette (23W) in the monsoon trough followed.

Next came Angela (24W) which formed in the monsoon trough in the South China Sea and became the anchor-low for the multiple storm outbreak which contained Brian (25W), Colleen (26W) and Dan (27W). As a subset of this event, Brian's binary interaction with Colleen at the end of the third week of October resulted in Colleen slowly executing a broad loop before tracking westward. The last week of October, Elsie (28W) and Tropical Depression 29W kept the activity going until the short pause before Forrest (30W) consolidated the second week of November. Forrest became part of another multiple storm outbreak that included Gay (31W) and Hunt (32W). As the subtropical ridge strengthened and pushed equatorward, Forrest tracked from the Philippine Sea westward across the South China Sea and the Gulf of Thailand, and ultimately recurved in the Bay of Bengal. Hunt recurved on 20 November and Gay, which was long-lived and required 63, six-hour warnings, recurved on 30 November to close out the year.

#### JANUARY THROUGH MAY

Typhoon Axel (01W), the first significant tropical cyclone to occur in 1992 in the western North Pacific, developed in the first week of January in conjunction with two other tropical cyclones — Betsy (11P) and later Mark (12P) — in the Southern Hemisphere in response to an equatorial west wind burst to the east of New Guinea. Axel's early intensification at a low latitude proved particularly damaging to the Marshall and eastern Caroline Islands. During the last week of January, Ekeka (01C), which formed south of the Hawaiian Islands, became a rare January central North Pacific hurricane. Due to increasing upper-level wind shear, Ekeka had weakened to 40 kt (20 m/sec) when the JTWC assumed warning responsibility on 4 February. The weakening tropical cyclone continued to move westward and passed through the Marshall Islands.

#### JUNE

After a four month hiatus in tropical cyclone activity in the western North Pacific Ocean, **Bobbie (02W)** developed in the monsoon trough in the central Caroline Islands in late June. Bobbie's formation coincided with that of **Chuck's (03W)** over the central Philippine Islands, and the two underwent binary interaction for three days. As Typhoon Bobbie passed east of northern Luzon, torrential rains, associated with the deep monsoonal flow into Bobbie and enhanced by Chuck, caused heavy rains, mudslides, and widespread flooding over the northern half of the Philippines. After, recurving and tracking just to the southeast of Okinawa, Bobbie accelerated in forward motion, and underwent extra-tropical transition before passing just south of Tokyo. Chuck was the first significant tropical cyclone of the year in the South China Sea. **Deanna (04W)** was the third, and final, significant tropical cyclone to form in June. Deanna executed a counter-clockwise loop on 27 and 28 June in the western Caroline Islands before moving out to the northwest on a track parallel to the one taken by Bobbie five days earlier.

#### JULY

After Deanna recurved on 2 July, ridging temporarily replaced the monsoon trough across the northern Philippine Islands and Philippine Sea. Weak southwesterlies, however, persisted at low latitudes and **Eli (05W)** formed in the eastern Caroline Islands. Slow to intensify, Typhoon Eli tracked rapidly west-northwestward across Luzon, the South China Sea, and into northern Vietnam. Next came **Faye (06W)**, the second of three successive tropical cyclones to pass over northern Luzon and intensify in the South China Sea. Recurving south of Hong Kong on 17 July, Faye proceeded north-northeastward into China and dissipated. **Gary (07W)** followed Faye, and after presenting

JTWC with early difficulties locating the low-level vortex, the Center correctly predicted that Gary would strike the southern coast of China near Hainan Dao. Gary caused widespread damage across southern China. Typhoon Gary's track paralleled those of Typhoon Eli and Tropical Storm Faye. The fourth of five significant tropical cyclones to develop in July, **Helen (08W)** intensified from a Tropical Upper Tropospheric Trough (TUTT)-induced low-level circulation. The tropical storm began to weaken as it gained latitude and moved into a region of cooler sea-surface temperatures. A few days later, **Irving (09W)** became the first of two successive typhoons to affect southwestern Japan. It formed at the eastern end of the monsoon trough where several low-level vorticity centers were embedded in a broad area of poorly organized convection. Irving slowly intensified and took a north-oriented track into southwestern Japan followed by westward motion toward Korea due to the reestablishment of the mid-level subtropical ridge.

## AUGUST

Four days after Irving hammered Shukoku, **Janis (10W)** slammed into Kyushu. Janis began near Pohnpei in the Caroline Islands, took a northwestward track threatening Okinawa, then recurved, passed over Kyushu, and skirted the western coast of Honshu before transitioning to an extratropical low over Hokkaido. The second of eight significant tropical cyclones to develop in August, **Kent (11W)** became the first super typhoon of 1992. During its trek toward Japan, Kent underwent binary interaction with Tropical Storm Lois. Requiring a total of 58 warnings, Kent was second only to Super Typhoon Gay for the highest total number of warnings and longevity for the western North Pacific in 1992. Next came **Lois (12W)**, one of only two tropical cyclones in 1992 which had a persistent eastward component of motion during its period of warning. The storm bedeviled

JTWC forecasters by consistently moving counter to the climatologically expected motion. After escaping the binary interaction with Kent, Lois accelerated northeastward and dissipated over colder water. **Mark (13W)** was part of a multiple storm outbreak with Kent, Lois, and later, Nina. On 15 August, Mark's genesis in the South China Sea in the monsoon trough coincided with Lois' in the Philippine Sea, as deep low-level southwesterly flow surged eastward across the Philippine Islands. Due to strong vertical wind shear, Mark was slow to intensify and spent its short lifetime embedded in the monsoon trough. It dissipated over southern China. **Nina (14W)**, part of the multiple storm outbreak in August with Kent, Lois and Mark, formed as a TUTT-induced tropical cyclone under divergent upper-level flow east of Kent. Nina intensified to a peak intensity of 45 kt (23 m/sec) despite the strongly sheared environment. On 20 August, the second super typhoon of 1992, **Omar (15W)** developed in the southern Marshall Islands, moved steadily west-northwestward and intensified. On 28 August, Omar wreaked havoc on Guam as it rapidly intensified immediately prior to passing directly over the island. Typhoon Omar was the most damaging typhoon to strike Guam since Typhoon Pamela in 1976, causing an estimated \$457 million of damage. After traversing Guam, Omar continued onward into the Philippine Sea where it briefly attained super typhoon intensity. Omar then steadily weakened, passing over Taiwan as a tropical storm, and dissipated over southeastern China. **Polly (16W)**, the eighth and final significant tropical cyclone of August, developed along with Omar as part of a major relocation of the monsoonal trough. Polly was unusual in that throughout most of its life, it maintained the structure of a monsoon depression with a ring of peripheral gales and a broad band of deep convection around a large, relatively cloud free, central area of light-and-variable winds. The outflow aloft from Polly appeared to play an important role in

delaying the intensification of Omar, when Omar was approaching Guam. Although Polly never reached typhoon intensity, it did have quite an impact on eastern Asia.

## SEPTEMBER

The first of five significant tropical cyclones to form in September, **Ryan (17W)** became part of a multiple storm outbreak, including Omar and Sibyl, east of 150° east longitude. Although Ryan initially took a west-northwestward course similar to the two preceding tropical cyclones (Polly and Omar), it later stalled, and then acquired a north-orientated track. Two days after transitioning to an extratropical low east of Hokkaido, the remnants of Ryan could still be identified, as an occluded low continuing northward over Siberia, north of the Sea of Okhotsk. **Sibyl (18W)**, like Ryan, formed at the extreme eastern end of the monsoon trough. But unlike Ryan, Sibyl underwent a complex interaction with a cyclonic cell in the TUTT, and later recurved. For five days, Sibyl exhibited erratic motion and slowly intensified near Wake Island, before moving to the northwest and recurving. A short respite ensued for JTWC while the disturbance that was to become Typhoon **Ted (19W)** slowly developed. Ted was marked by moderate to strong upper-level wind shear throughout most of its life. A combination of shearing effects and land interaction prevented Ted from intensifying above minimal typhoon. Ted's tour of Asia included northern Luzon, northeastern Taiwan, eastern China, and finally Korea before the circulation transitioned to a weak extratropical cyclone over the Sea of Japan. The next tropical cyclone, **Val (20W)**, was the only one of five typhoons in September that did not intensify beyond a tropical storm. Like Ted, which formed a day earlier on 18 September, Val was slow to intensify. Next came **Ward (21W)** which formed in the trade wind trough just to the east of the international date line. Ward presented considerable difficul-

ty to JTWC forecasters, as it underwent two major track changes and two significant acceleration episodes.

## OCTOBER

The first of eight significant tropical cyclones to form in October, **Zack (22W)** was also the first to threaten the southern Mariana Islands since Omar's devastating passage across Guam in August. Initially its movement was to the west-northwest along the axis of the monsoon trough, but a monsoon surge of deep southwesterly winds resulted in an abrupt track change to the north-northeast for Zack. As the tropical storm weakened, the low-level circulation center became difficult to locate, and JTWC issued a final warning on Zack on 12 October. However, by the following day, the convection and organization of the system had increased, prompting JTWC to issue a "regenerated" warning. Zack briefly reintensified to a tropical storm before transitioning into a subtropical system and dissipating over the ocean. The third Northwest Pacific tropical cyclone of 1992 to achieve super typhoon intensity was **Yvette (23W)**. It formed at the same time as Zack and proved to be an action-packed system which posed many forecast challenges. In the span of two weeks, Yvette developed in a moderately sheared environment, made a run toward Luzon as it intensified to a typhoon, stalled, executed a major, 150-degree track change, weakened, reintensified to a super typhoon, and transitioned to an extratropical cyclone. During the second week of October, **Angela (24W)** developed in the South China Sea, moved east, reversed course and struck southern Vietnam. Angela later crossed southern Indochina and reintensified to a severe tropical storm in the Gulf of Thailand, where it tracked through a clockwise loop, and finally dissipated over the Gulf. While anchoring the western end of a monsoon trough, Angela became part of a multiple storm outbreak along with Brian, Colleen



and Dan. Angela posed a significant threat in the Gulf of Thailand, where manned gas platforms were forced to evacuate as the storm intensified and moved into the area. Forming in the southern Marshall Islands, **Brian (25W)** moved west-northwestward and intensified into a midget typhoon as it passed across Guam. For Guam, it was the second eye passage in less than two months - Omar being the first. Later, Brian underwent binary interaction with Typhoon Colleen, subsequently recurved, and finally transitioned to an extratropical system. **Colleen (26W)** developed from a broad cyclonic circulation in the monsoon trough between Typhoon Angela to the west and Typhoon Brian to the east. Binary interaction occurred between Colleen and Brian, causing Colleen to make a slow anticyclonic loop in the Philippine Sea before turning west. After crossing Luzon, Colleen reintensified into a typhoon before slamming into central Vietnam and dissipating inland. The last significant tropical cyclone to develop in October as part of the four storm outbreak, **Dan (27W)** became the most destructive typhoon to strike Wake Island in the past quarter-century, causing an estimated \$9.0 million in damage. Just as Ekeka and Ward did earlier in 1992, Dan formed east of the international date line, marking the first time that three significant tropical cyclones were observed to cross into the JTWC's area of responsibility from the central North Pacific during a single year. Later, Dan faked a move toward recurvature, took a west-southwesterly course, underwent an episode of reintensification, and finally, underwent a binary interaction with Typhoon Elsie before recurving sharply. Next came the fourth super typhoon of 1992, **Elsie (28W)**, which was the third typhoon to pass within 60 nm (100 km) of Guam in less than three months. After initial movement to the northeast in response to a southwest monsoonal surge, a subsequent turn to the west, and then interaction with Typhoon Dan, which brought Elsie to the north toward the southern Mariana Islands, the

tropical cyclone settled down on a track to the northwest, recurved, and transitioned into a hurricane-force extratropical low.

## NOVEMBER AND DECEMBER

Forming in the wake of Typhoon Dan, **Tropical Depression 29W** immediately became a threat to Wake Island which had already been heavily damaged by Dan on 28 October. Fortunately for Wake Island, the Tropical Depression's intensification was severely curtailed by the persistent outflow from Dan. The second of four significant tropical cyclones to get started in November, **Forrest (30W)** became part of a three storm outbreak with Gay and Hunt. Forrest was the only tropical cyclone of 1992 to track from the western North Pacific, across the South China Sea, and into the Bay of Bengal. It reached a maximum intensity of 125 kt (64 m/sec) in the Bay of Bengal over a day after it had recurved. A day after Forrest became a tropical storm, **Hunt (32W)** developed and became the fourth typhoon to pass within 60 nm (110 km) of Guam in less than three months. Hunt was part of a three storm outbreak with Tropical Storm Forrest and Super Typhoon Gay. As Hunt intensified, it brushed by Guam, moved into the Philippine Sea, and later recurved. After recurvature, the typhoon played an important role in the extremely rapid weakening of Super Typhoon Gay which was approaching the southern Mariana Islands. **Gay (31W)** developed at the same time as Hunt. Gay was noteworthy for five reasons: its eye became the record third to pass across Guam in less than three months; it was estimated to be the most intense tropical cyclone to occur in the western North Pacific since Super Typhoon Tip in October of 1979; it went through two intensification periods, which is not rare but is relatively uncommon; it filled an estimated 99 mb in less than 48 hours without moving over land; and, it required the highest number of warnings, 63, for any western North Pacific tropical

cyclone in 1992. Four days after being detected as a tropical disturbance, Gay slammed into several of the Marshall Islands with typhoon force winds. After peaking with sustained winds of 160 kt (82 m/sec) with gusts to 195 kt (100 m/sec), the super typhoon weakened for two days before reaching Guam. Typhoon Gay passed across the center of Guam on 23 November, then reintensified to a second peak before recurving on 30 November, and dissipating over water south of Japan. No significant tropical cyclones occurred in the western North Pacific in December.

Composite best tracks for the western North Pacific tropical cyclones this year are provided in Figures 3-6, 3-7 and 3-8.

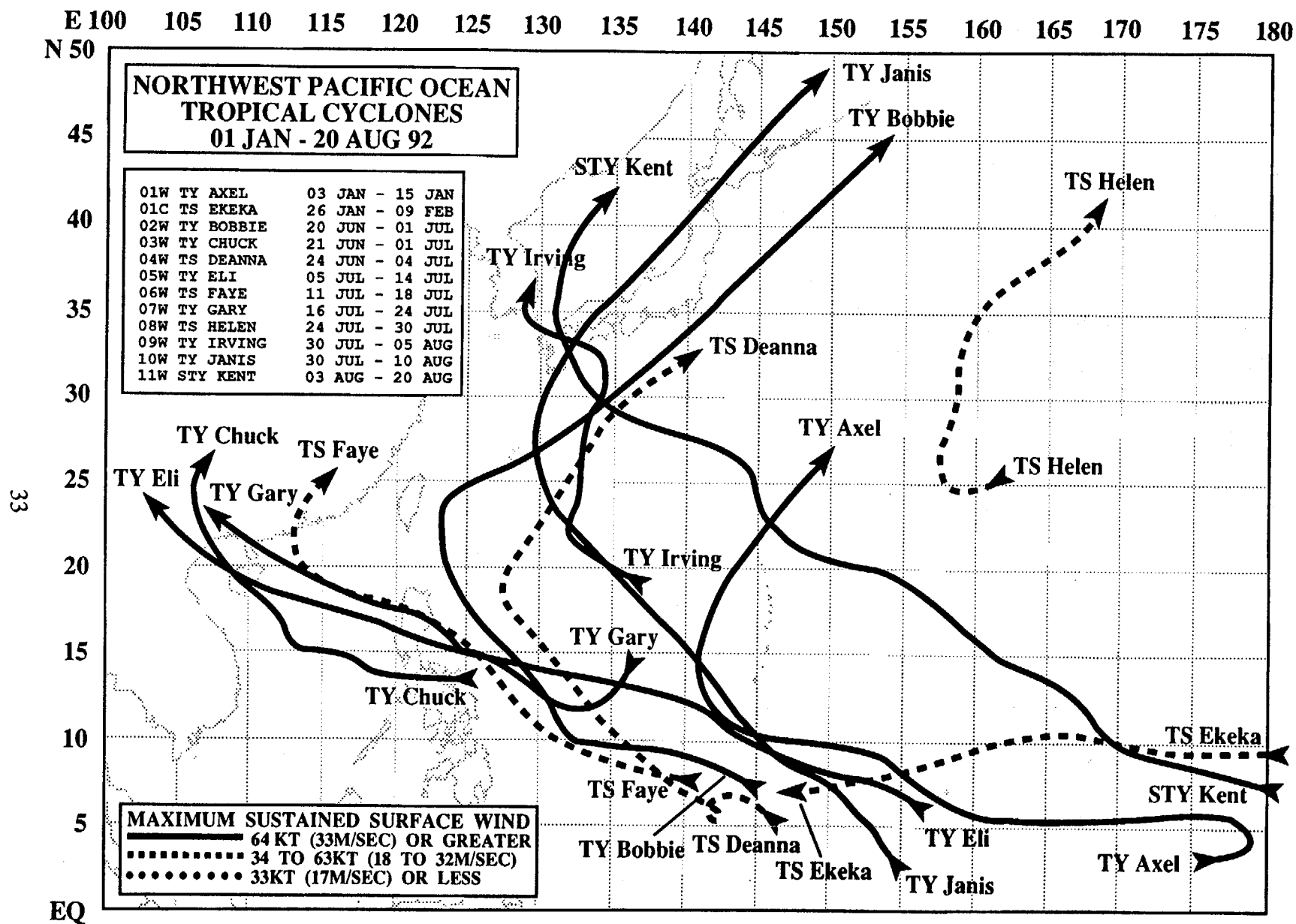


Figure 3-6. Composite best tracks for Northwest Pacific Ocean Tropical cyclones for 01 January to 20 August 1992

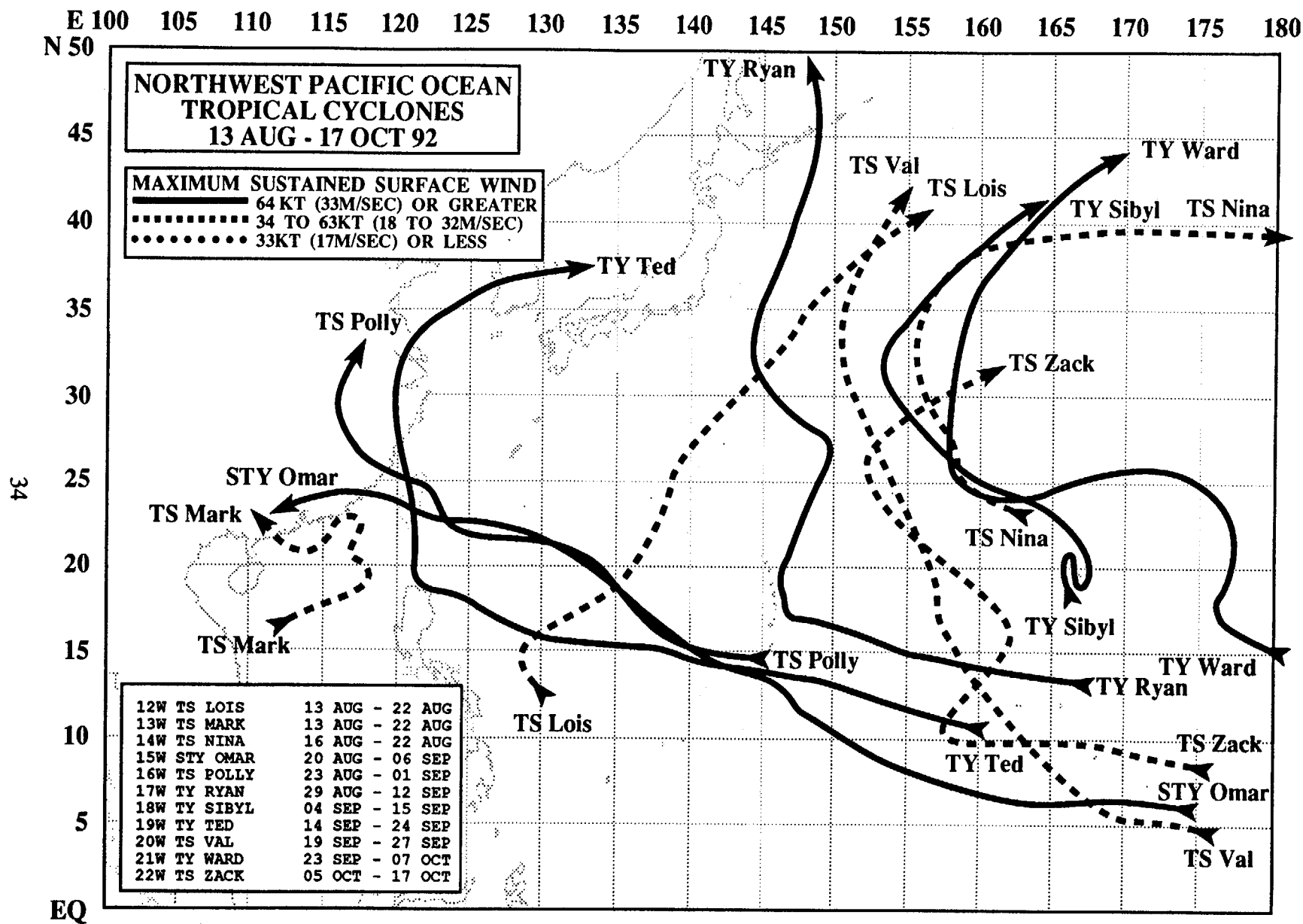


Figure 3-7. Composite best tracks for Northwest Pacific Ocean Tropical cyclones for 13 August to 17 October 1992.

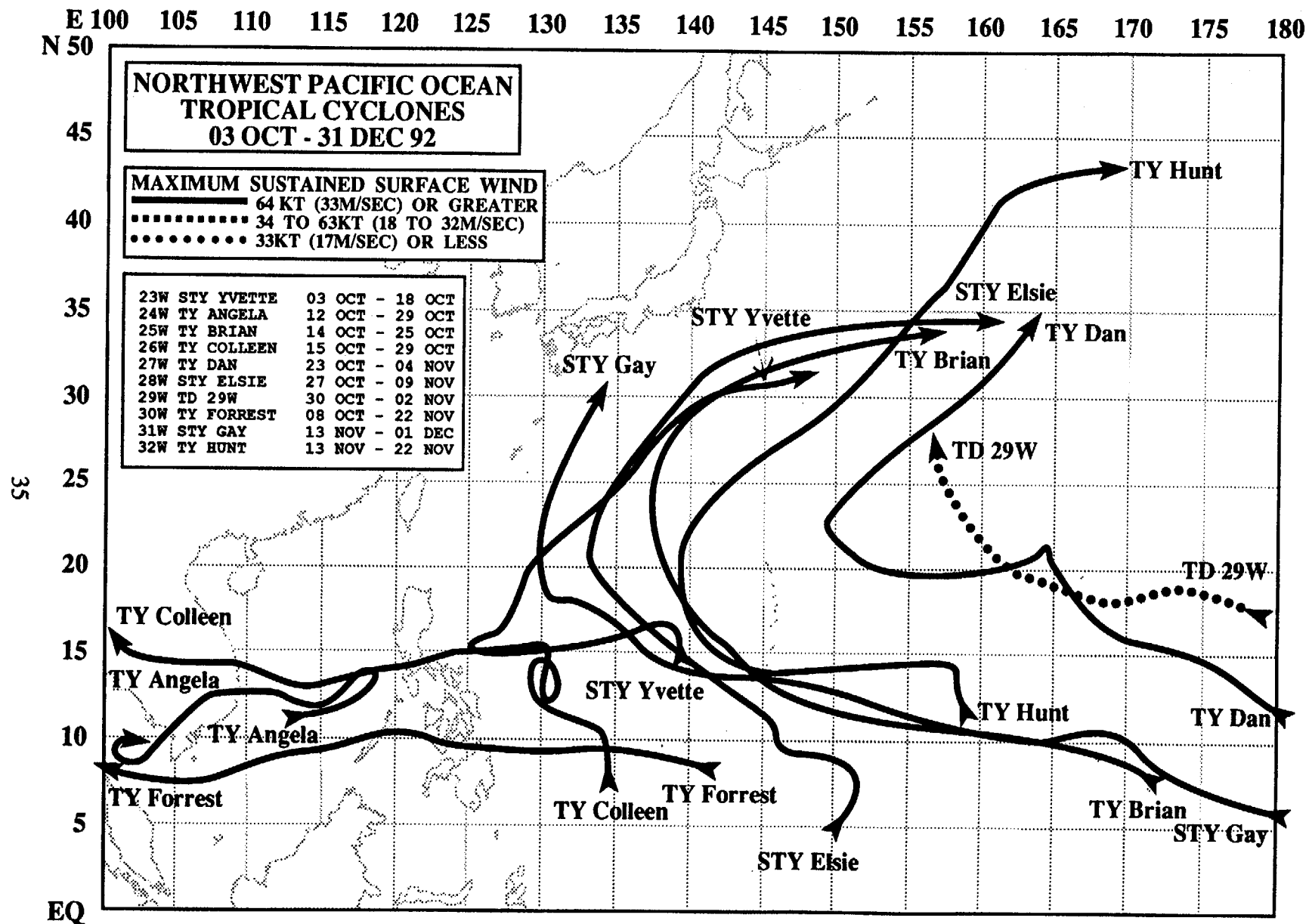
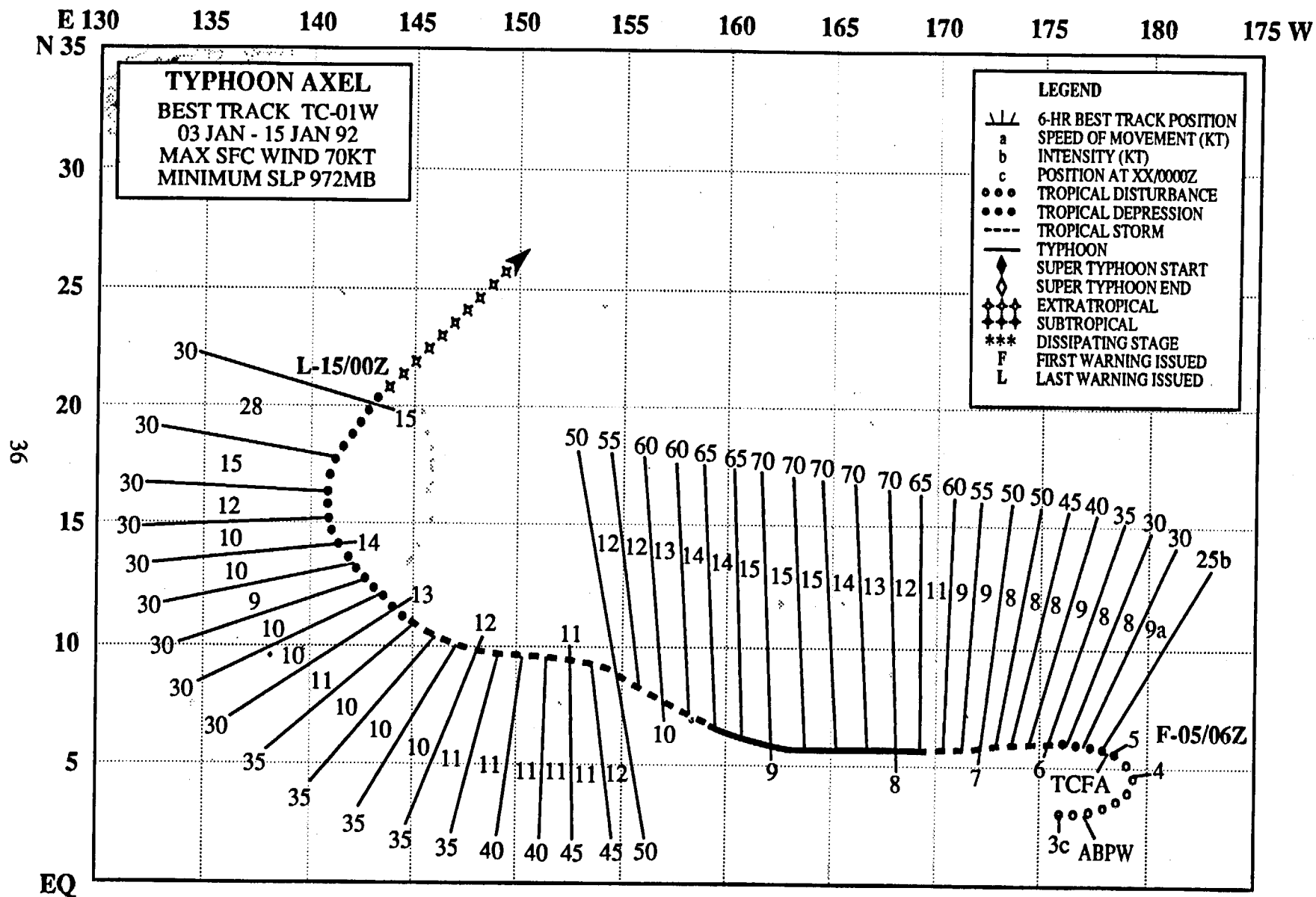


Figure 3-8. Composite best tracks for Northwest Pacific Ocean Tropical cyclones for 03 October to 31 December 1992



## TYPHOON AXEL (01W)

### I. HIGHLIGHTS

Typhoon Axel was the first significant tropical cyclone to occur in 1992 in the western North Pacific. It developed in January in conjunction with an equatorial west wind burst to the east of New Guinea along with two other tropical cyclones — Betsy (11P) and later Mark (12P) — in the Southern Hemisphere. Axel's early intensification at a low latitude proved particularly damaging to the Marshall Islands.

### II. TRACK AND INTENSITY

Stronger than normal low-level westerly winds along the equator were noted east of New Guinea when Tarawa (WMO 91610) in the Gilbert Islands reported 28 kt (14 m/sec) gradient-level winds at 011200Z, 37 kt (19 m/sec) gradient-level winds at 020000Z, and later, at 030000Z, Banaba Island (WMO 91533) 300 nm (555 km) to the southwest of Tarawa reported surface winds of 30 kt (15 m/sec). These increased winds and an area of maximum cloudiness persisted in the area, as twin cyclones began to form. Axel was to the north and Betsy (11P) to the south of the equator. The evolution of these twin cyclones, and later a third, Mark (12P) located to the west of Betsy (11P), is graphically illustrated as cloud silhouettes in Figure 3-01-1. The persistent convection, which was to become Axel, was first mentioned on the Significant Tropical Weather Advisory at 030600Z. As the equatorial westerly winds died down, the convection began to consolidate around the twin disturbances. This prompted the issuance of a Tropical Cyclone Formation Alert on Axel at 050030Z, and the first warning at 050600Z. Strong upper-level divergence over the area enhanced development of the cloud system and Axel (Figure 3-01-2) attained tropical storm intensity based on Dvorak intensity estimates at 060000Z just before slamming into the Marshall Islands. Later, at 070000Z, an 85 kt (44 m/sec) ship report from the SV Cherokee became the basis for an upgrade to typhoon intensity. (In post analysis, comparison of the 85 kt (44 m/sec) report with observations from the nearby islands of Majuro (WMO 91376), Mili (WMO 91378), Jaluit (WMO 91369) and Ailinglapalap (WMO 91367) caused the SV Cherokee's to be questioned.)

By 8 January, Axel and Betsy (11P) were both at typhoon intensity and the distance between the two was steadily increasing with Axel headed west and Betsy (11P) south. After Axel reached a peak intensity of 70 kt (36 m/sec) at 080000Z, the typhoon passed just north of Kosrae and Pingelap (Figure 3-01-3) in the eastern Caroline Islands. Continuing to track south of the subtropical ridge axis and westward towards Guam, the typhoon weakened due to increasing vertical wind shear. As a consequence, JTWC downgraded Axel to a tropical storm at 091800Z, shortly after the cyclone passed 15 nm (30 km) north of Pohnpei (WMO 91348), where a maximum sustained winds of 30 kt (15 m/sec) and a peak gust to 48 kt (25 m/sec) were reported. Six hours after being downgraded to a tropical depression at 130000Z, Axel passed 90 nm (165 km) to the southwest of Guam. The tropical cyclone recurved a day later. As Axel was transitioning to an extratropical low and accelerating into the mid-latitude westerly flow, JTWC issued the final warning on the system at 150000Z.

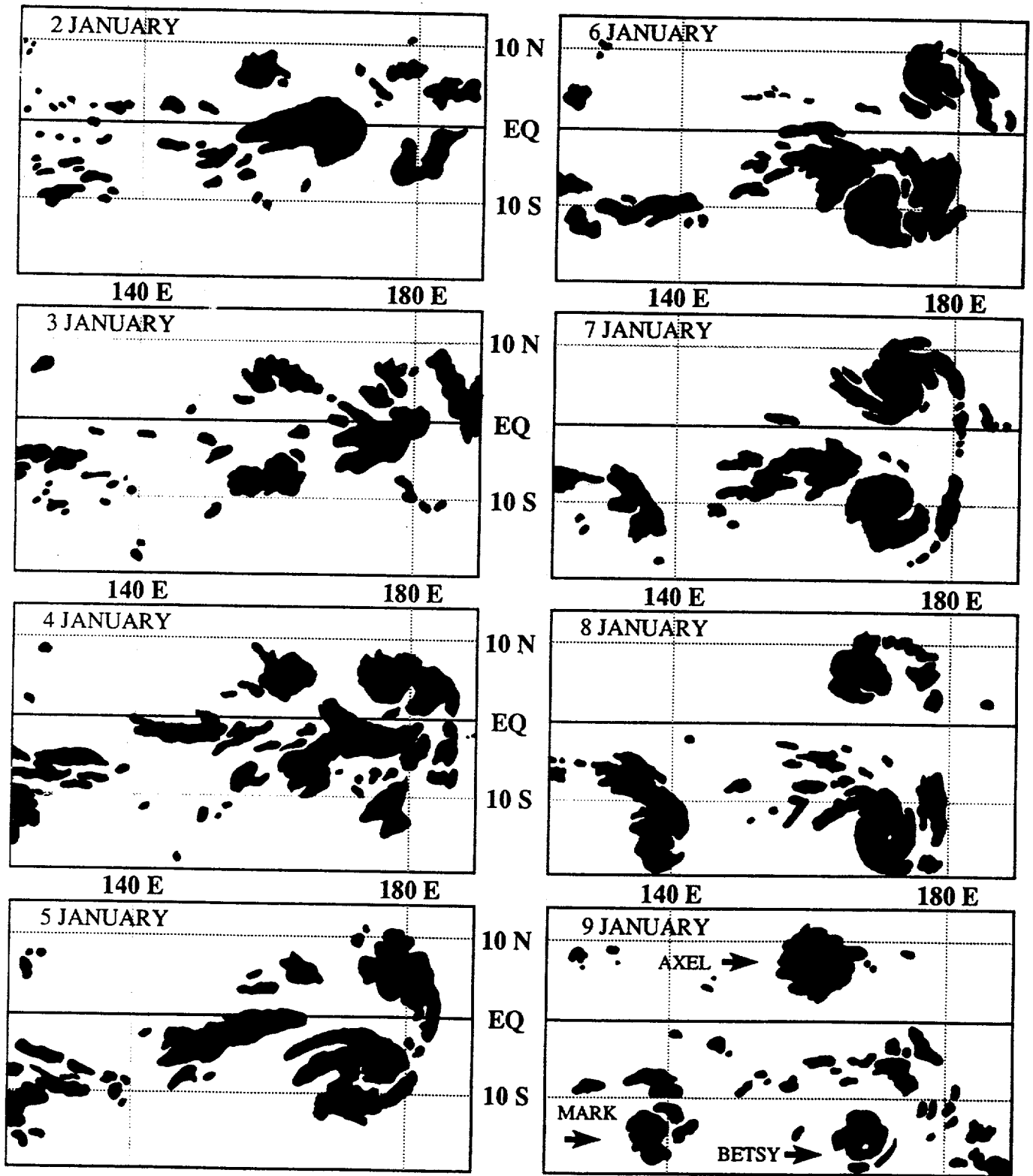


Figure 3-01-1. Cloud silhouettes for the period 2 to 9 January show the development of Axel, Betsy (11P) and later, Mark (12P). As the equatorial convection decreases, the cloudiness consolidates in the twin cyclones in opposite hemispheres.



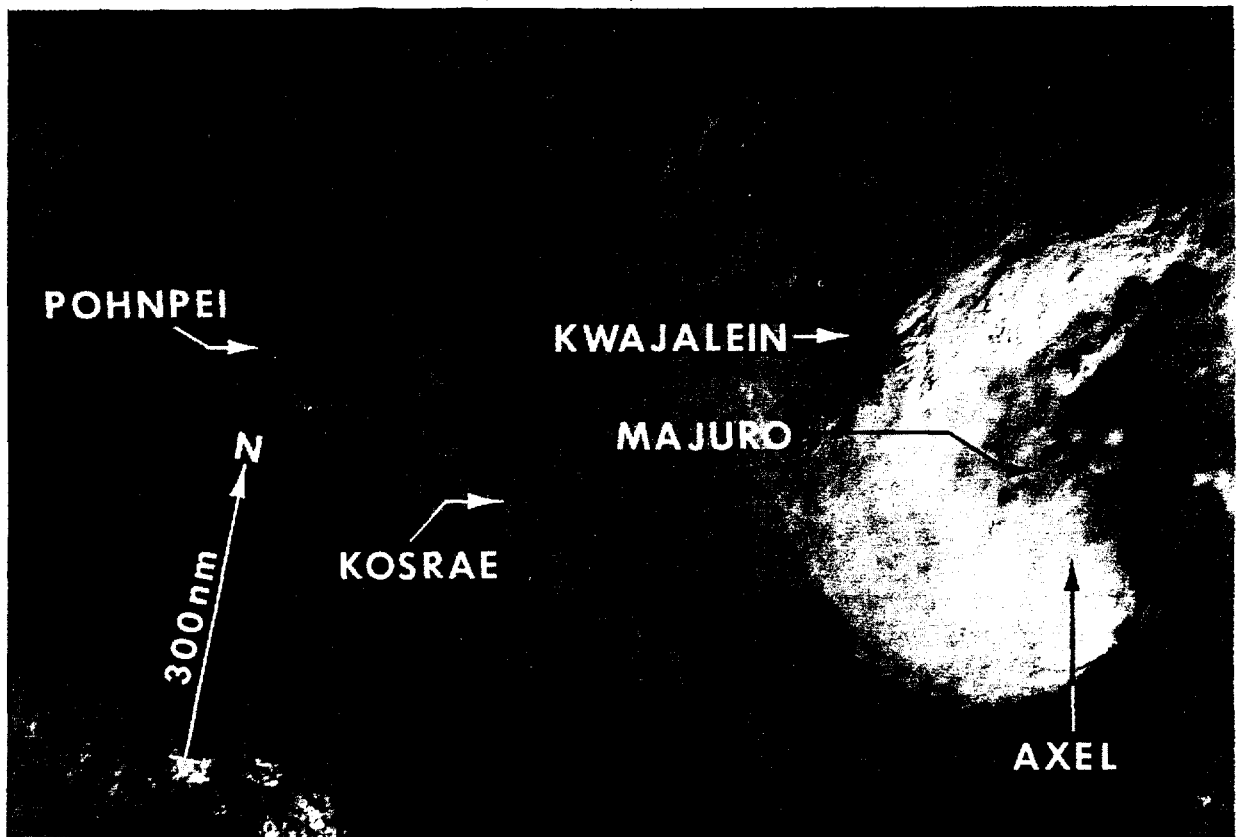


Figure 3-01-2. Axel's convection coils up as the tropical cyclone intensifies over the Marshall Islands (062211Z January DMSP visual imagery).

### III. FORECAST PERFORMANCE

The overall mean track errors were 93 nm (172 km), 152 nm (282 km), and 183 nm (339 km) for the 24-, 48-, and 72-hour forecasts respectively. However, JTWC forecasts for a straight runner to the west were longer than needed resulting in larger forecast errors near the point of recurvature where there was a question as to where, or when, a break would appear in the subtropical ridge to allow Axel to track northward.

With regard to the intensity, the initial forecasts based on the development of twin cyclones and strong upper-level divergence, and discussed in the first several prognostic reasoning messages, verified well.

### IV. IMPACT

Axel created havoc in the Marshall Islands. In the tropical cyclone's wake, the Federal Emergency Management Agency (FEMA) provided more than two million dollars to over 1300 people requesting assistance on Majuro and four other atolls. Axel washed out airport runways, ruined water reservoir systems, ruined crops and vegetation, and left hundreds of people without roofs over their heads. Mili, the easternmost atoll to be affected, took a direct hit. Houses were blown down and many trees and crops were lost.

Majuro (WMO 91367) experienced peak gusts of 46 kt (24 m/sec) and a low pressure of 997.0 mb as Axel passed 75 nm (139 km) to the south. Unfortunately for Majuro, Axel's closest point of approach coincided with high tide. The high surf, estimated to be in the 13 to 16 foot range on top of the high tide, broke pipes and washed sand, coral rock, and debris onto the island's runway which doubles as a water catchment system and provides almost 90% of the fresh drinking water. Despite the fact that almost 10 inches (254 mm) of rain from Axel fell in a 24-hour period, salt water contaminated most of the water supplies on the island. Sanitation became an immediate problem due to water wells, tanks and toilets being damaged by Axel's passage. The airport was closed for five days while bulldozers were used to clear off the larger debris. The south shore reefs were damaged when huge chunks of coral were ripped out and rolled across the reef. Trees, brush and other debris from the land washed onto the reefs adding to the loss. On land, food crops were ruined by the wind and flooding.

Then, Axel passed across Jaluit Atoll and over four feet of water covered most of the main islands. The strong winds deposited rocks and coral debris on runway and washed away portions of airstrip. Additionally, over one half of the outhouses were destroyed, resulting in serious health concerns for the islanders. Farther north, Kwajalein Atoll, 170 nm (315 km) north of track, experienced maximum sustained winds of only 25 with gusts to 35 kt (10 G 18 m/sec) and reported no damage or injuries.

In the eastern Caroline Islands, Kosrae (WMO 91356) which was 40 nm (75 km) south of track experienced maximum sustained winds of 65 G 80 kt (33 G 41 m/sec) resulting in severe crop losses, trees and vegetation damaged, and some wooden and tin-roofed structures destroyed. Just south of track, Pingelap (Figure 2) and Mokil atolls located east of Pohnpei had their airstrips 60% damaged by the storm surge and the runways were closed for months afterward for repairs. Some wood and tin roofed structures were destroyed. An estimated 50-60% of the small vegetation, such as bananas, was lost, plus some large coconut and breadfruit trees uprooted. As Axel passed 15 nm (30 km) north of the Pohnpei, the island's electrical power was knocked out for 8 hours and houses and building in low-lying areas flooded. Banana and breadfruit trees suffered extensive damage. The storm surge was estimated at 15 feet on the offshore islands and 9.73 inches (247 mm) of rain was recorded in a 24-hour period as the cyclone passed. And finally, Axel was weakening as it passed 90 nm (170 km) southwest of Guam, where no damages or injuries were reported.

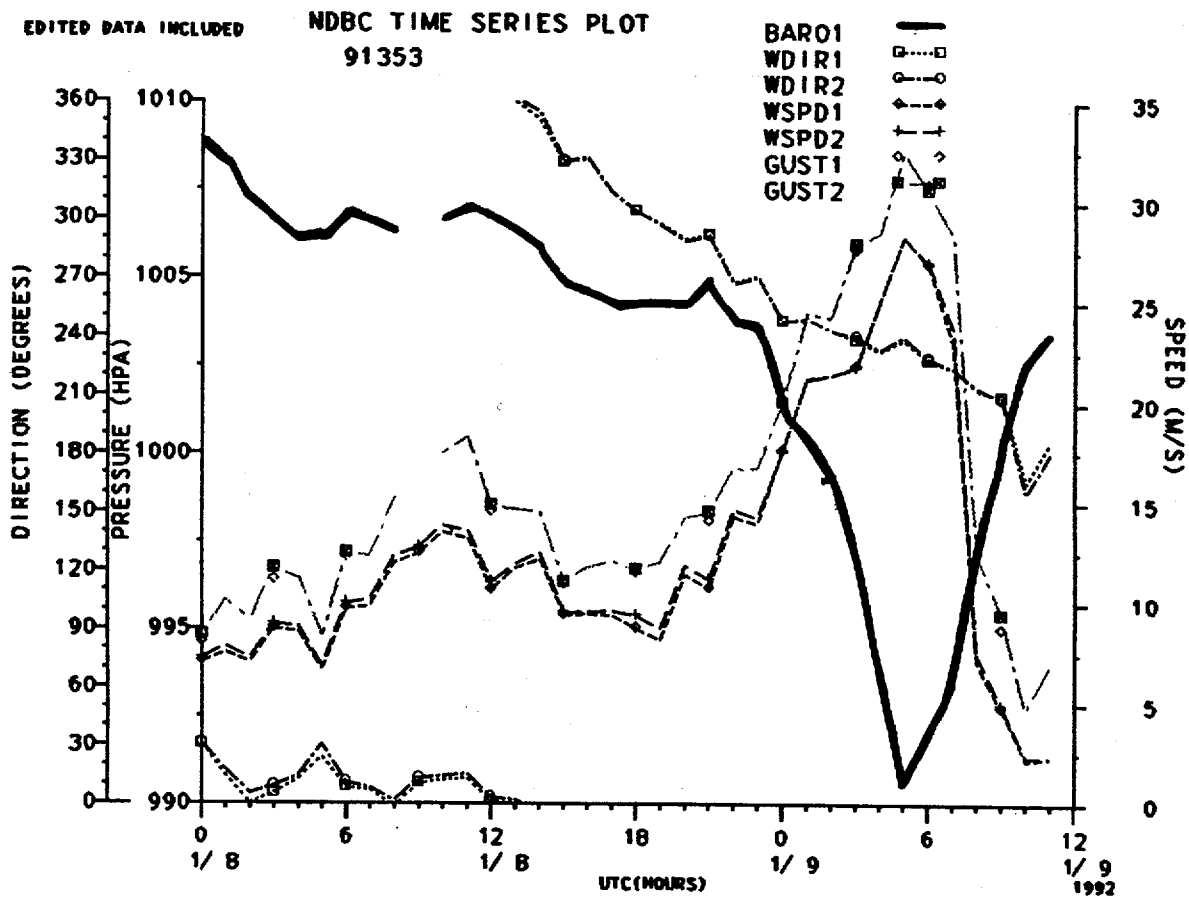
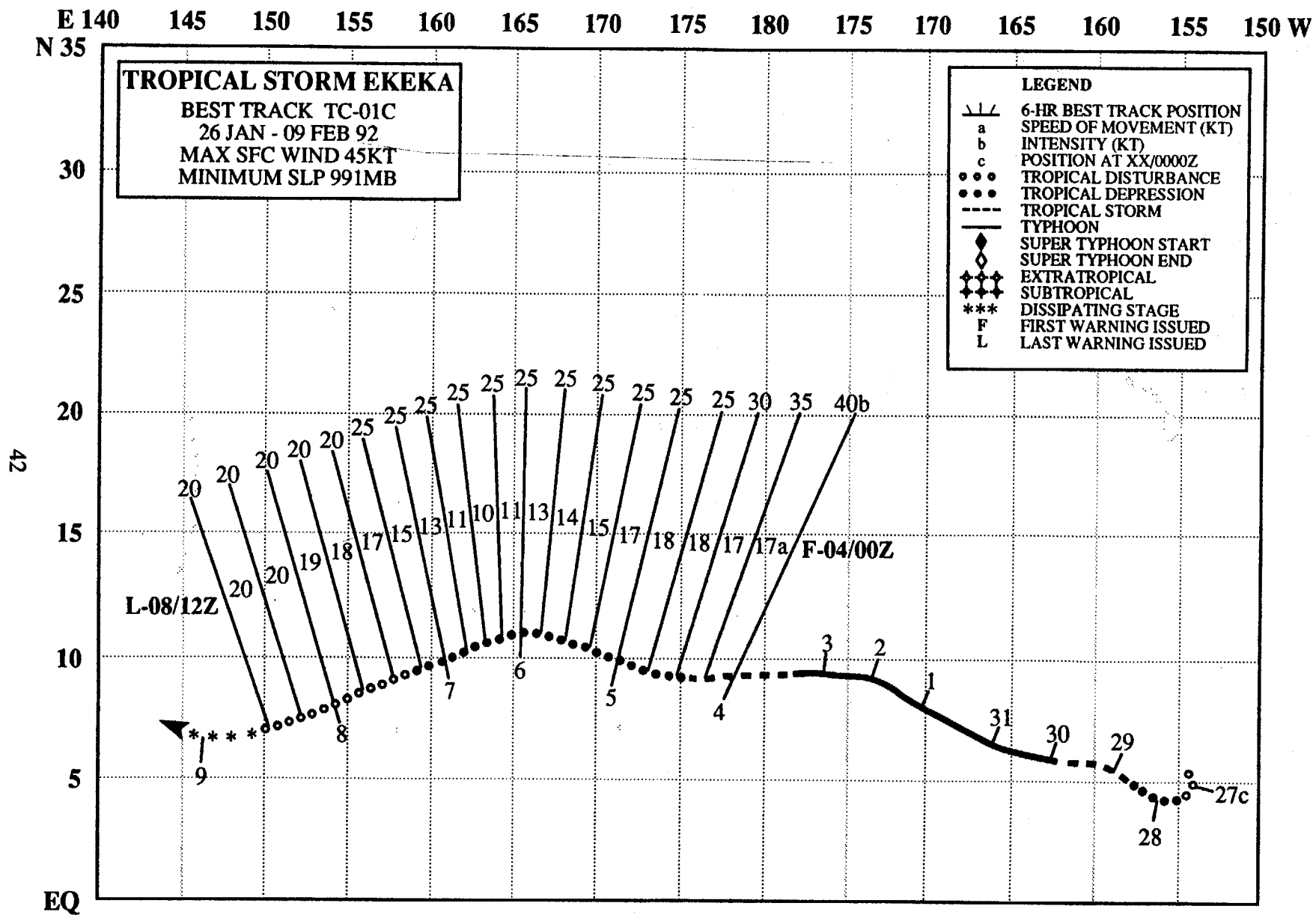


Figure 3-01-3. The Pingelap AMOS (WMO 91353) time series plot courtesy of the National Data Buoy Center shows surface winds gusting to 33 m/sec (64 kt) from the northwest and a minimum pressure of 991 mb at 090500Z as Axel passes by to the north.



## TROPICAL STORM EKEKA (01C)



Figure 3-01C-1. Ekeka a day before reaching its peak intensity while east of the international date line. Oahu appears at the top right (312001Z January GOES visual imagery courtesy of the National Weather Service Forecast Office, Honolulu, Hawaii).

After forming south of the Hawaiian Islands, Ekeka became a rare January central North Pacific hurricane which weakened and crossed into JTWC's area of responsibility. The tropical disturbance was initially detected by the Central Pacific Hurricane Center on 26 January, and the first warning was issued at 280600Z on Tropical Depression 01C, when it was 980 nm (1815 km) south of Oahu. On a track to the west-northwest, Ekeka intensified steadily over the next several days, reaching a peak intensity of 95 kt (50 m/sec) on 01 February. Then, the hurricane turned westward and began to accelerate as the subtropical ridge north of the system strengthened. Due to increased upper-level shear, Ekeka began to weaken, so that when the JTWC assumed warning responsibility at 040000Z, the maximum winds had dropped to 40 kt (20 m/sec). Within 12 hours, the tropical storm had further weakened to a tropical depression. Tropical Depression 01C continued to move westward in the deep easterly trade wind flow and passed through the Marshall Islands without causing any significant damage. After the tropical depression

passed over Chuuk (WMO 91334) where maximum winds of 17 kt (9 m/sec) were reported, JTWC issued the final warning at 081200Z. No reports of damage were received.

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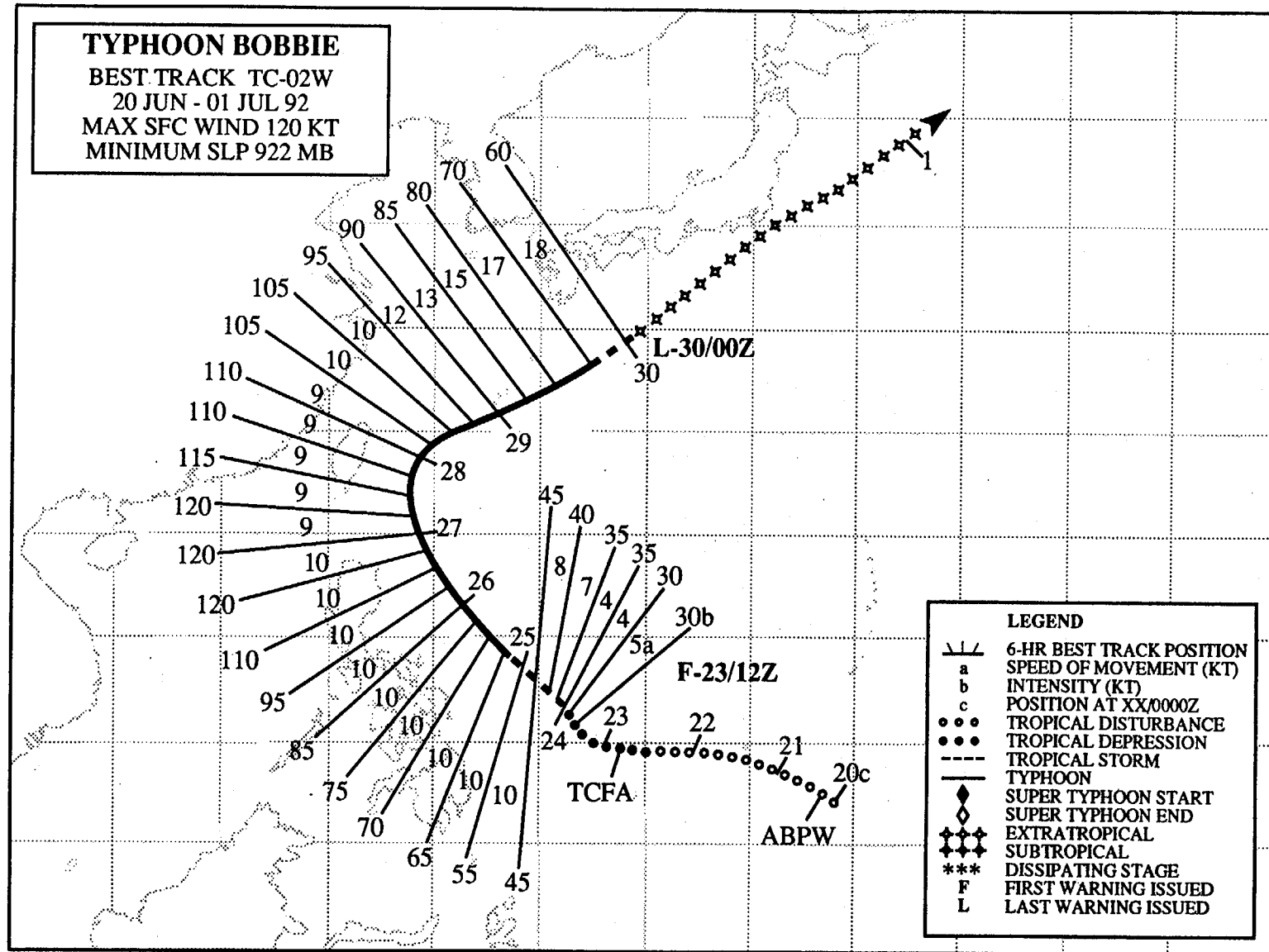
# **TYPHOON BOBBIE**

BEST TRACK TC-02W

20 JUN - 01 JUL 92

MAX SFC WIND 120 KT

MINIMUM SLP 922 MB



## **LEGEND**

- 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◆ SUPER TYPHOON END
- ◆ EXTRATROPICAL
- ◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

## **TYPHOON BOBBIE (02W)**

### **I. HIGHLIGHTS**

The second typhoon of the year, Bobbie formed in the monsoon trough in late June after a four month hiatus in tropical cyclone activity in the western North Pacific Ocean. Bobbie's formation in the central Caroline Islands coincided with that of Chuck (03W) over the central Philippine Islands, and the two underwent binary interaction for three days. Bobbie reached typhoon intensity several days prior to recurving. After recurvature, the typhoon accelerated, tracked just to the southeast of Okinawa and underwent extra-tropical transition before passing just south of Tokyo.

### **II. TRACK AND INTENSITY**

By 15 June, the monsoon trough became established in its normal climatological location across the South China Sea, the central Philippine Islands and extended into the Caroline Islands. Bobbie was the first significant cyclone to form in this trough. The tropical disturbance was detected as a poorly organized area of convection south of Guam near Woleai Atoll in the central Caroline Islands and first mentioned on the Significant Tropical Weather Advisory at 200600Z. Development of the circulation continued and JTWC issued a Tropical Cyclone Formation Alert at 221900Z followed by the first warning at 231200Z. At the same time, a second tropical cyclone, Chuck (03W), formed farther to the west in the monsoon trough over the central Philippine Islands. Due to the proximity of the two cyclones, binary interaction occurred during the period between 240600Z and 271200Z. The binary pair remained within 750 nm (1390 km) of each other and appeared to undergo relative cyclonic rotation about a common midpoint for three days (Figure 3-02-1).

Bobbie tracked northwestward and was upgraded to a typhoon at 250600Z. Intensification continued until a peak of 120 kt (62 m/sec) (Figure 3-02-2) was reached at 261800Z. By this time, Bobbie had also reached the western extent of the mid-level subtropical ridge where recurvature began to the east of Taiwan at 271200Z. As gradual acceleration began under increasing southwesterly winds aloft, Bobbie passed over Miyako Jima on 28 June and then just southeast of Okinawa on 29 June. Kadena AB, Okinawa reported the closest point of approach of 24 nm (44 km), a peak wind of 68 kt (35 m/sec), and a minimum sea-level pressure of 978 mb at 290028Z. When Bobbie underwent extratropical transition on 30 June southeast of Kyushu, JTWC issued the final warning on the system at 300000Z. The intense low pressure center with associated gale force winds brushed by the southern tip of Honshu and proceeded out to sea.

### **III. FORECAST PERFORMANCE**

After the fact, Bobbie's best track appears to be a straight forward case of recurvature. At the start however, based on persistent westward movement of Bobbie in the formative stages of development and the guidance provided by the dynamic aids, the forecast philosophy was for a straight running track west-northwestward along the axis of the monsoon trough. It appears that the development of Typhoon Chuck (03W) to the west, and the resulting binary interaction, influenced Bobbie's track change to the northwest. Later, when gradual recurvature was expected to occur, as Bobbie approached the ridge axis situated near 25° North Latitude, the western extension of the subtropical ridge eroded faster than depicted by the dynamic model and the typhoon recurved earlier and at a lower latitude. From the recurvature point, the tropical cyclone was forecast to pass to the west of Okinawa. At 280600Z, the strengthening of the upper-level jet south of Honshu was noted, and at 281800Z the track

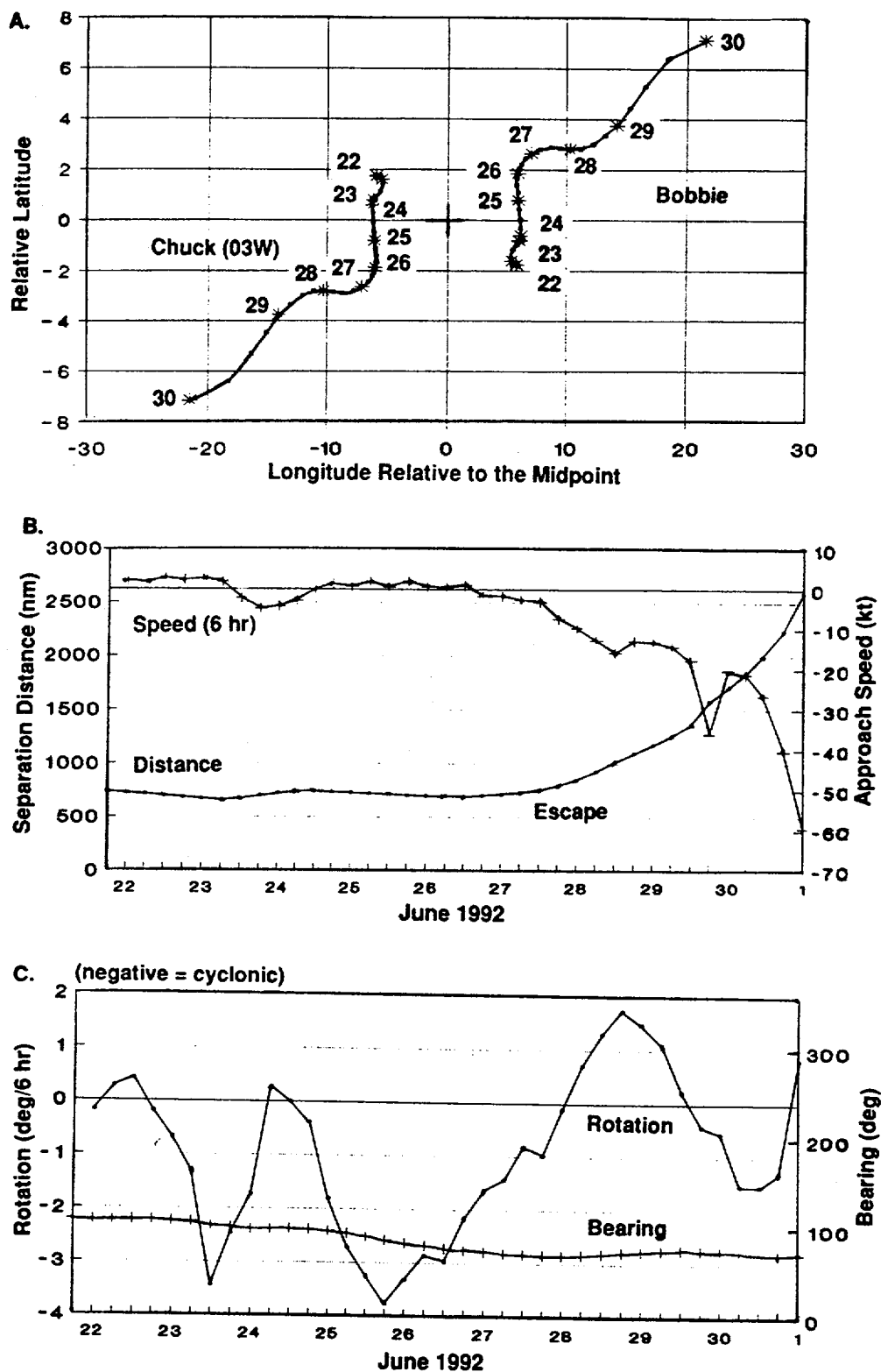


Figure 3-02-1. A set of graphs depict the binary interaction between Bobbie and Chuck (03W). The motion relative to a common midpoint is shown in (A), nearly constant 750 nm (1390 km) separation in (B), and cyclonic rotation in (C).



forecast was adjusted correctly for Bobbie to pass to the east of Okinawa. Despite the shift in the forecast track, ample warnings and detailed prognostic reasoning messages evaluating the potential for alternate scenarios gave Okinawa enough time and information to adequately prepare.

With respect to intensity forecasts, the errors were quite large initially due to the expected interaction with rugged northern Luzon which did not occur. And later, in like fashion, the forecast interaction with Taiwan didn't occur and the typhoon intensified over water.

#### IV. IMPACT

As the typhoon passed east of the northern Luzon, torrential rains associated with the deep monsoonal flow into Bobbie and enhanced by Chuck (03W) caused heavy rains, mudslides, and widespread flooding over the northern Philippine Islands. These conditions were aggravated in the area of Mount Pinatubo when a "secondary" volcanic explosion occurred on 27 June, triggering flows of lava, mud, ash, and sand up to 5 feet deep down the mountains sides. No deaths or injuries were reported in the towns near the volcano due to timely evacuations of the population. On 28 June, Bobbie passed over Miyako Jima. Okinawa was next. The island boarded up and schools were closed. On 29 June, these preparations paid off and only minor damage to buildings, property and vegetation occurred. Kadena Air Base reporting one trailer overturned and small trees uprooted. One woman received head injuries when she was knocked down by the strong wind.

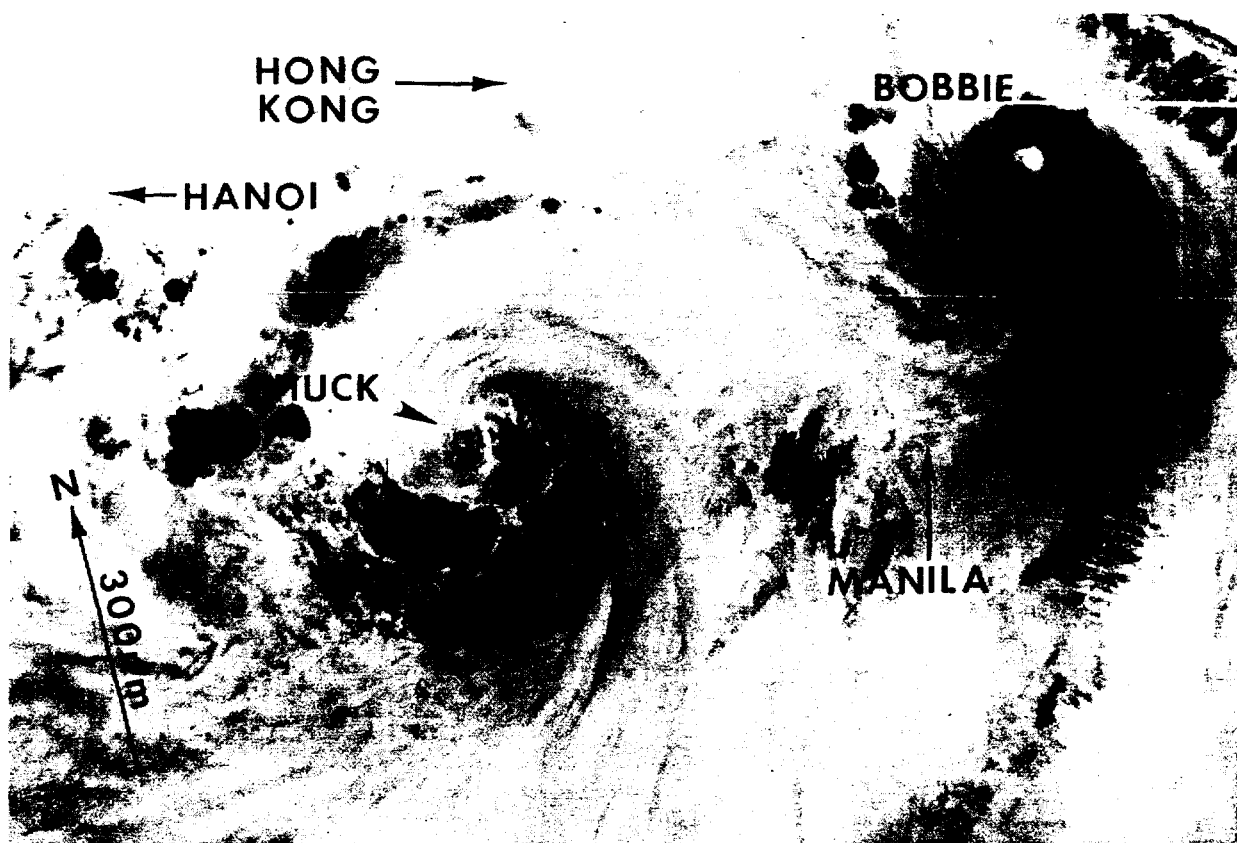


Figure 3-02-2. Typhoon Bobbie at a peak intensity of 120 kt (62 m/sec) and approaching its point of recurvature. Chuck (03W) can be seen over the South China Sea to the southwest of Bobbie (261949Z June NOAA infrared imagery).

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# **TYPHOON CHUCK**

BEST TRACK TC-03W

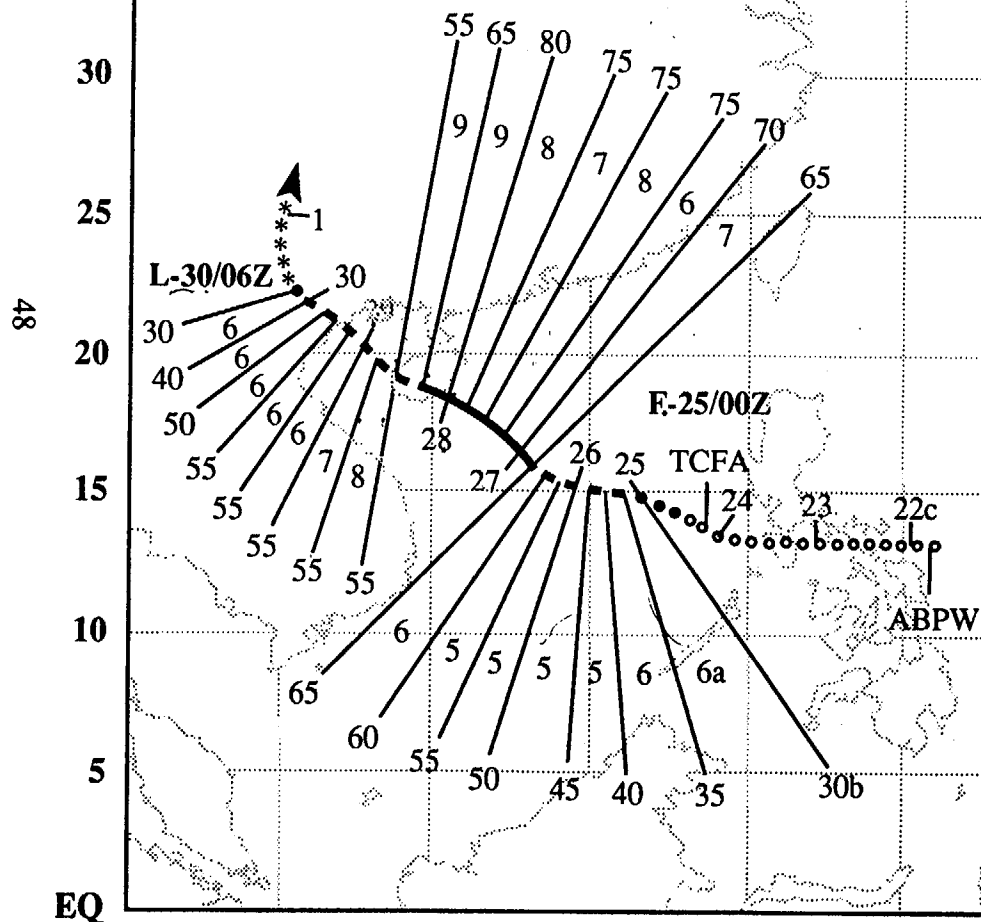
21 JUN - 01 JUL 92

MAX SFC WIND 80 KT

MINIMUM SLP 964 MB

## **LEGEND**

- 6-HR BEST TRACK POSITION
- SPEED OF MOVEMENT (KT)
- INTENSITY (KT)
- POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- SUPER TYPHOON START
- SUPER TYPHOON END
- EXTRATROPICAL
- SUBTROPICAL
- DISSIPATING STAGE
- FIRST WARNING ISSUED
- LAST WARNING ISSUED



## **TYPHOON CHUCK (03W)**

### **I. HIGHLIGHTS**

Chuck was the first tropical cyclone of the year in the South China Sea. Genesis occurred in the monsoon trough at the same time in late June as Bobbie (02W) and binary interaction took place over the first few days of development.

### **II. TRACK AND INTENSITY**

Chuck developed over the central Philippines as part of a multiple tropical cyclone outbreak, and the Significant Tropical Weather Advisory was reissued at 211900Z to include the event. In conjunction with this development, gradient-level wind reports as far to the west as the Malay Peninsula showed an overall increase of 10 kt (5 m/sec) to the 25-35 kt (13-18 m/sec) range. As the amount and organization of the convection continued to increase, JTWC issued a Tropical Cyclone Formation Alert at 240430Z. The first warning followed at 250000Z, and 12 hours later, Chuck was upgraded to a tropical storm based on satellite and ship synoptic reports. Tracking slowly along the monsoon trough axis, Chuck moved to the west-northwest as it underwent binary interaction with Bobbie (02W) (Figure 3-03-1). Even after 271200Z, when Typhoon Bobbie (02W) began to recurve and the separation distance between the two cyclones started to increase, Chuck showed very little change in track.

A wind report of 60 kt (31 m/sec) and a 981.4 millibar pressure from Xisha Qundao (WMO 59981), was the basis for upgrading Chuck to typhoon intensity at 271200Z. Xisha recorded a minimum sea-level pressure of 966.2 mb (Royal Observatory, June 1992) during the typhoon's passage. Chuck remained a typhoon until it hit the southern tip of Hainan Dao on 28 June. The station at Yaxian (WMO 59948) reported a pressure of 964.1 mb (Royal Observatory, June 1992) when the typhoon made landfall 20 nm (37 km) to the northeast. Chuck weakened slightly as it passed over the southern tip of Hainan Dao, crossed the Gulf of Tonkin and slammed in northern Vietnam on 29 June. The final warning was issued at 300600Z, as Chuck dissipated over land.

### **III. FORECAST PERFORMANCE**

The overall mean errors were 106 nm (196 km), 207 nm (380 km) and 331 nm (610 km) for the 24-, 48-, and 72-hour track forecasts respectively. At the start, larger track errors were associated with forecasts based on a more westerly straight-running track in agreement with the dynamic guidance that turned out to be to the left of track. And later, forecasts based on premature recurvature to the north were to the right of track.

### **IV. IMPACT**

Navy patrol aircraft from Kadena Air Base and Cubi Point NAS, Philippines, searched for two ships in distress and 22 crew members missing after Typhoon Chuck crossed the South China Sea. Only flotsam, oil slicks, and other debris were found. On Hainan Dao, one death and 19 injuries were reported, plus extensive damage to houses and crops. In northern Vietnam, at least 21 people died and 80 were reported missing. In addition, many watercraft were sunk, houses destroyed, and power lines downed.

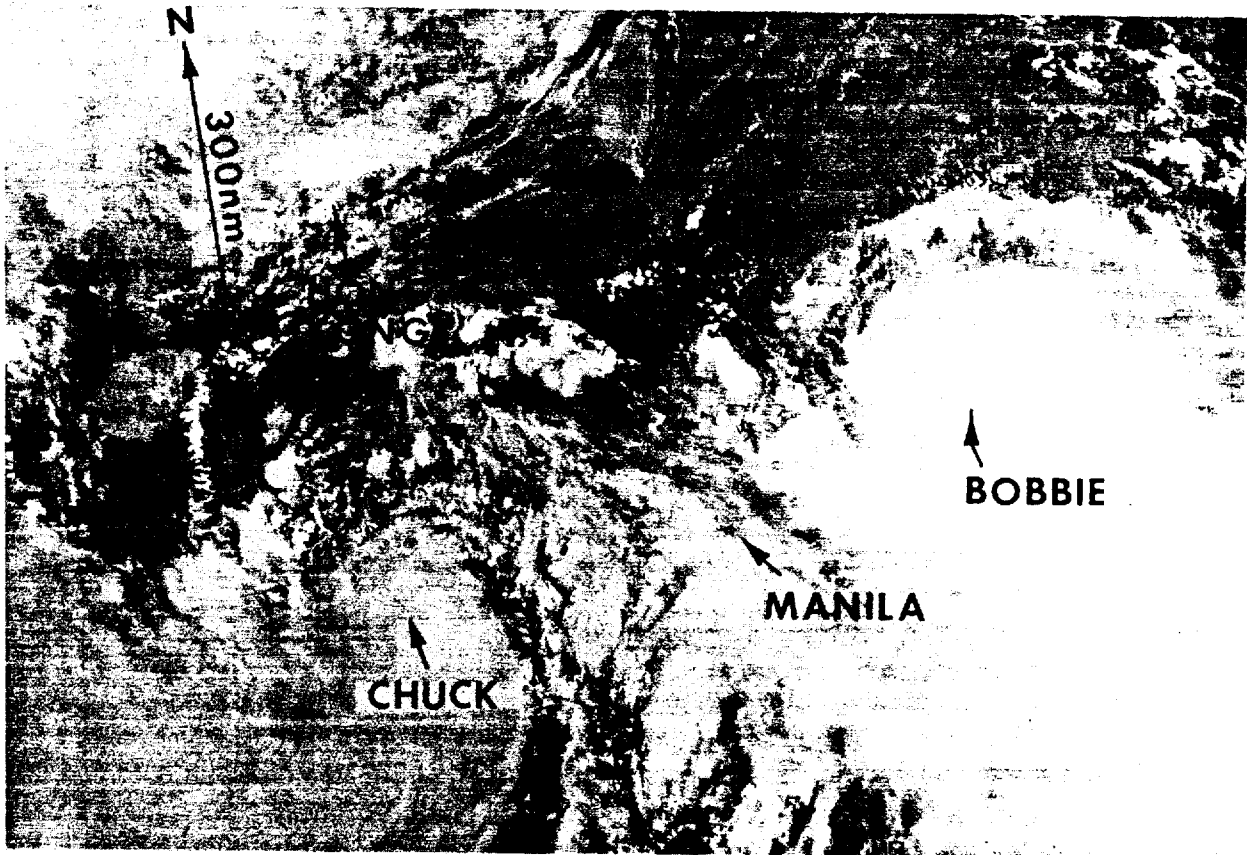
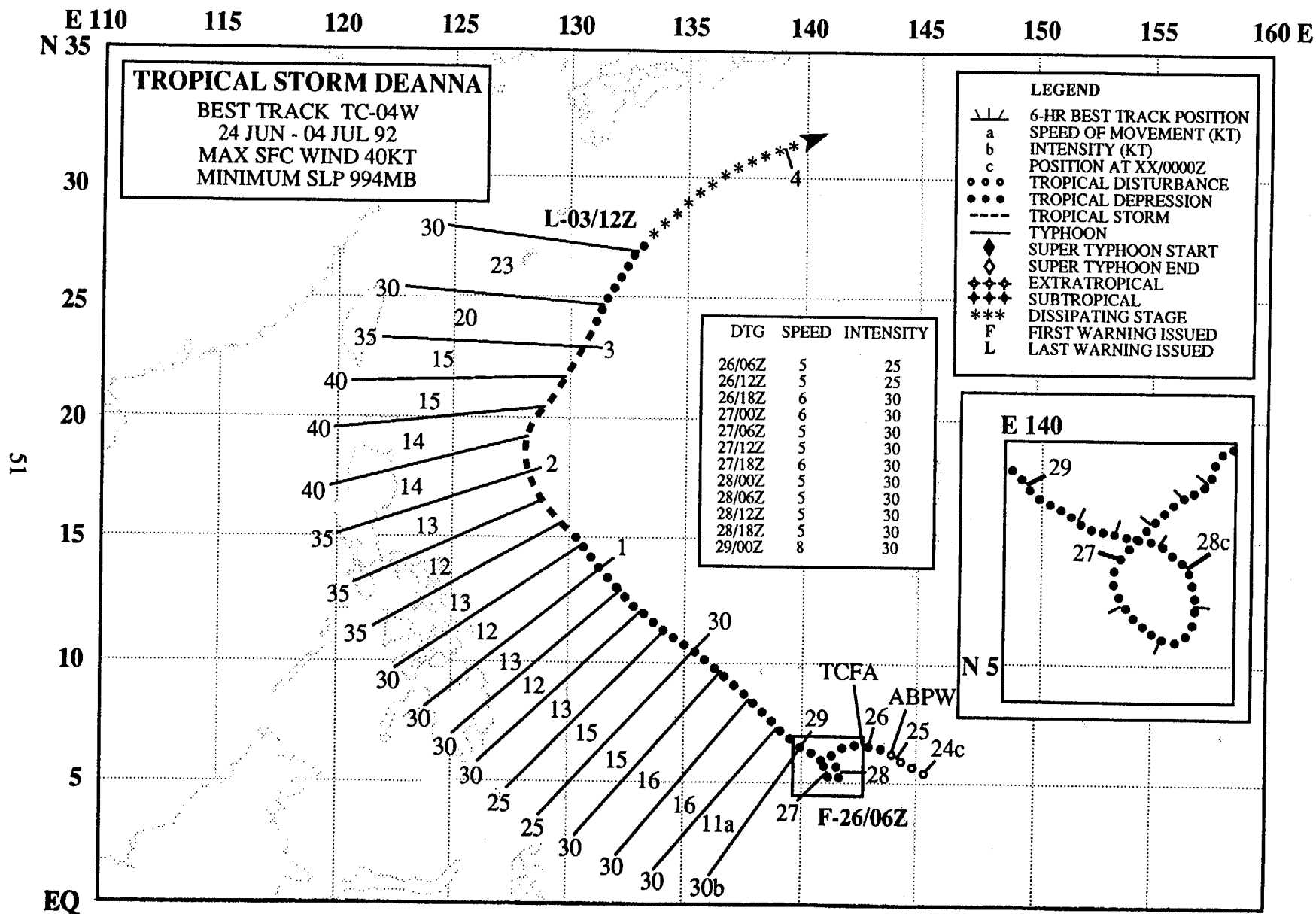


Figure 3-03-1. Chuck at tropical storm intensity churns across the South China Sea and interacts with Typhoon Bobbie (02W) located to the east-northeast (252353Z June NOAA visual imagery).



## TROPICAL STORM DEANNA (04W)

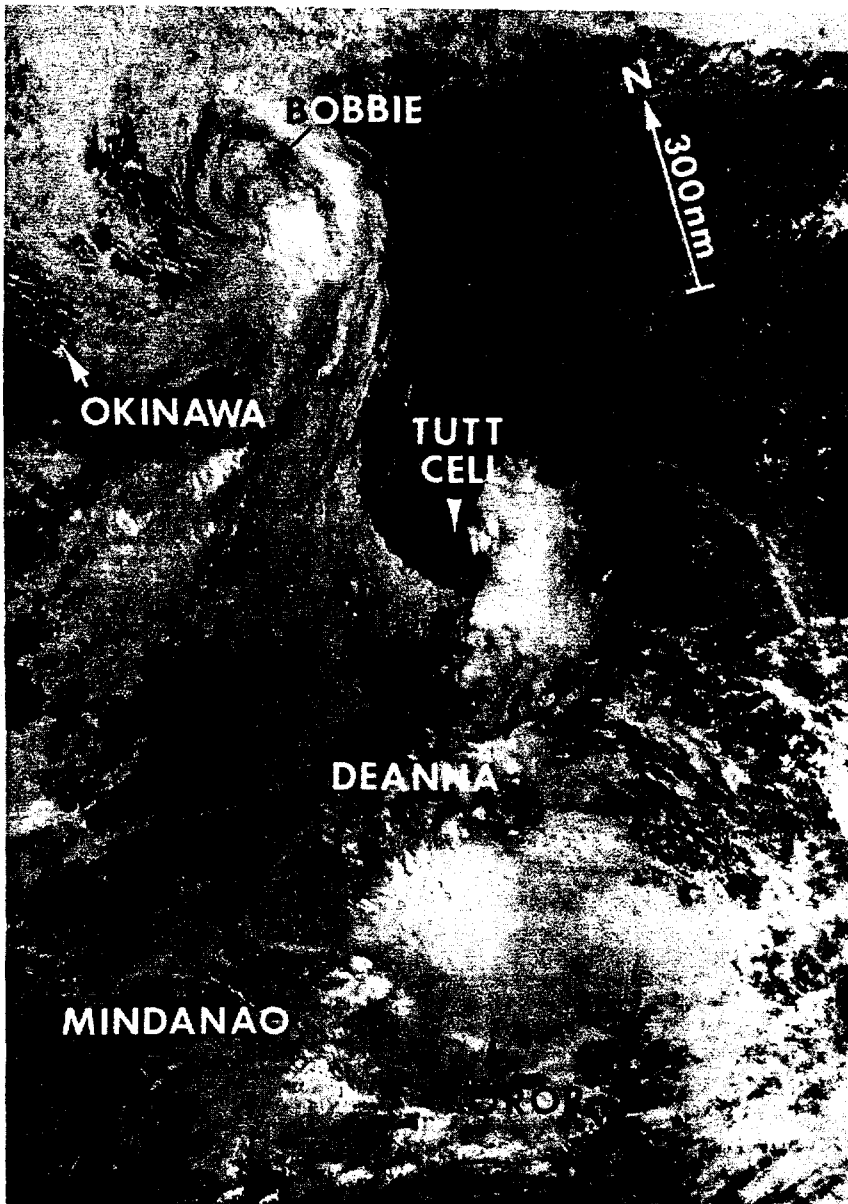


Figure 3-04-1. Deanna's convection was slow to organize due to the vertical wind shear from Bobbie's (02W) outflow and flow around the associated TUTT cell to the north (300945Z June DMSP visual imagery).

Deanna was the third, and final, significant tropical cyclone to form in June. After first mention at 250600Z on the Significant Tropical Weather Advisory, it was the subject of a Tropical Cyclone Formation Alert at 260300Z, and a first warning at 260600Z. Deanna executed a counter-clockwise loop on 27 and 28 June before moving out to the northwest on a track paralleling the one taken by Bobbie (02W) five days earlier. After reaching a peak intensity of 40 kt (21 m/sec) at 020600Z July near the subtropical ridge axis, the tropical storm accelerated to the northeast and dissipated in a frontal band. The final warning was issued at 031200Z.

E 100 105 110 115 120 125 130 135 140 145 150 155 160 E  
N 35

**TYPHOON ELI**  
BEST TRACK TC-05W  
05 JUL - 14 JUL 92  
MAX SFC WIND 75KT  
MINIMUM SLP 968MB

**LEGEND**

- △/△ 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

30

25

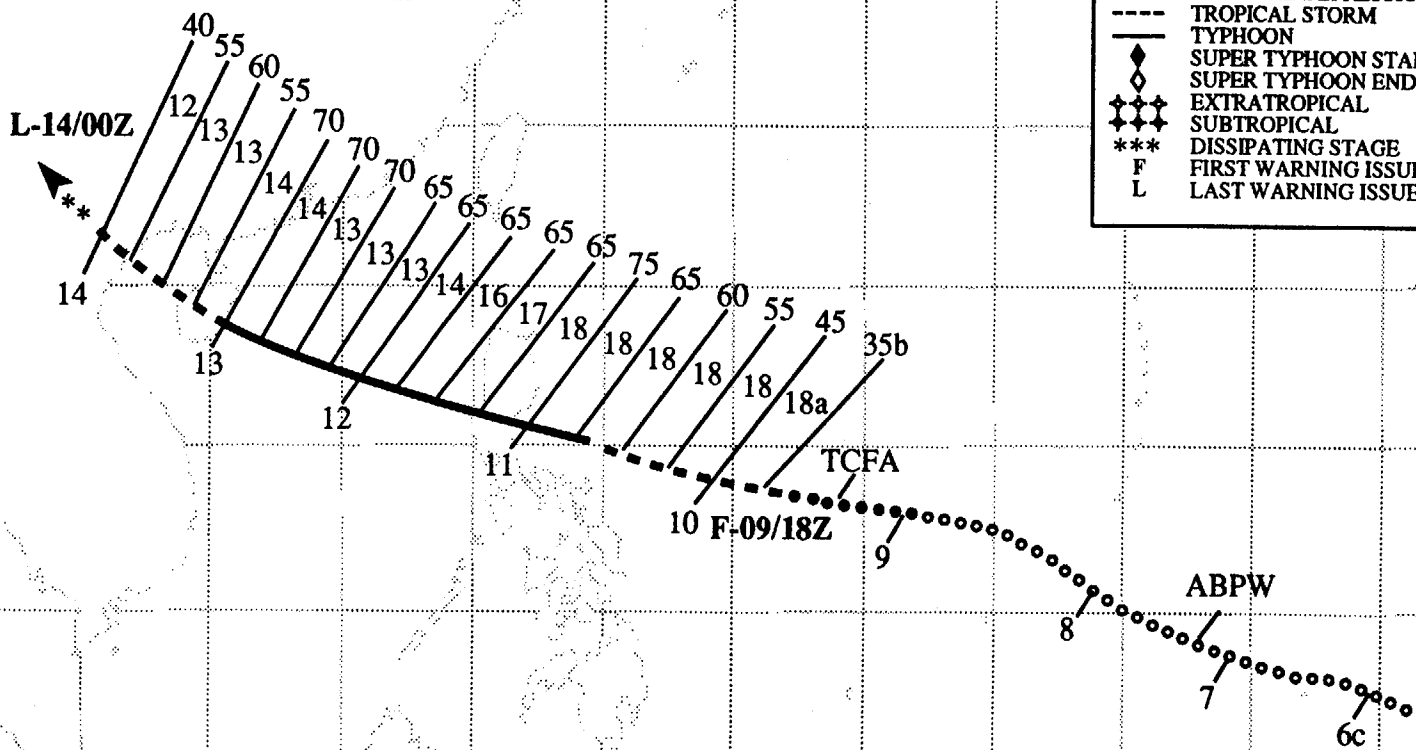
20

15

10

5

EQ



## **TYPHOON ELI (05W)**

### **I. HIGHLIGHTS**

The first significant tropical cyclone to develop in July, Eli formed in the eastern Caroline Islands, intensified into a typhoon while moving rapidly across the Philippine Sea, and tracked west-northwestward across Luzon, the South China Sea, and into northern Vietnam.

### **II. TRACK AND INTENSITY**

After Deanna (04W) recurved on 2 July, ridging temporarily replaced the monsoon trough across the Philippine Islands and Sea. To the east in the eastern Caroline Islands, however, weak southwesterlies persisted at low latitudes, and a weak cyclonic circulation developed. This circulation and its associated convection was first mentioned in the 070600Z Significant Tropical Weather Advisory. That night, a small mass of convection located in the eastern end of the circulation accelerated westward as a squall line. The squall's brief passage across Guam brought over a half inch of rain and winds gusting to 30 kt (15 m/sec). On 8 July, the tropical disturbance, after tracking to the south of Guam, accelerated to 19 kt (35 km/hr) and increased in organization, prompting JTWC to issue a Tropical Cyclone Formation Alert at 091100Z. The first warning followed at 091800Z as the convection increased throughout the night.

Tropical Depression 05W was upgraded to a tropical storm at 100000Z as Eli's convective buildup continued (Figure 3-05-1). Eli attained typhoon intensity at 101800Z, and peaked at 75 kt (39 m/sec) six hours later, just before making landfall on northern Luzon. Maximum sustained winds of 28 kt (14 m/sec) with gusts to 40 kt (21 m/sec) were reported by Cubi Point Naval Air Station as Eli passed 85 nm (155 km) to the north. After entering the South China Sea, the typhoon's forward motion slowed as the mid-level easterly steering flow weakened near the western end of the subtropical ridge. Eli maintained minimal typhoon intensity until it plowed into Hainan Dao on the night of 13 July. Then, as a tropical storm, Eli moved west-northwestward across the Gulf of Tonkin and dissipated over northern Vietnam on 14 July.

### **III. FORECAST PERFORMANCE**

The overall, mean track forecast errors for JTWC were 80, 138, and 157 nm (148, 256, and 291 km) at 24, 48 and 72 hours, respectively. In comparison with the other aids, these forecasts, plus the guidance provided by OTCM, showed skill when compared to CLIPER, which had mean track errors of 104, 171, and 225 nm (195, 317, and 417 km) at 24, 48 and 72 hours, respectively.

### **IV. IMPACT**

Torrential rains associated with Typhoon Eli caused mudflows in the Mount Pinatubo area on Luzon, where there were reports of three deaths. Regional civil defense authorities reported evacuating 1600 people from their homes in three central Luzon towns to escape avalanches of volcanic debris, or lahars, from Mount Pinatubo. In addition, 25 fishermen were reported missing off the east coast of Luzon.



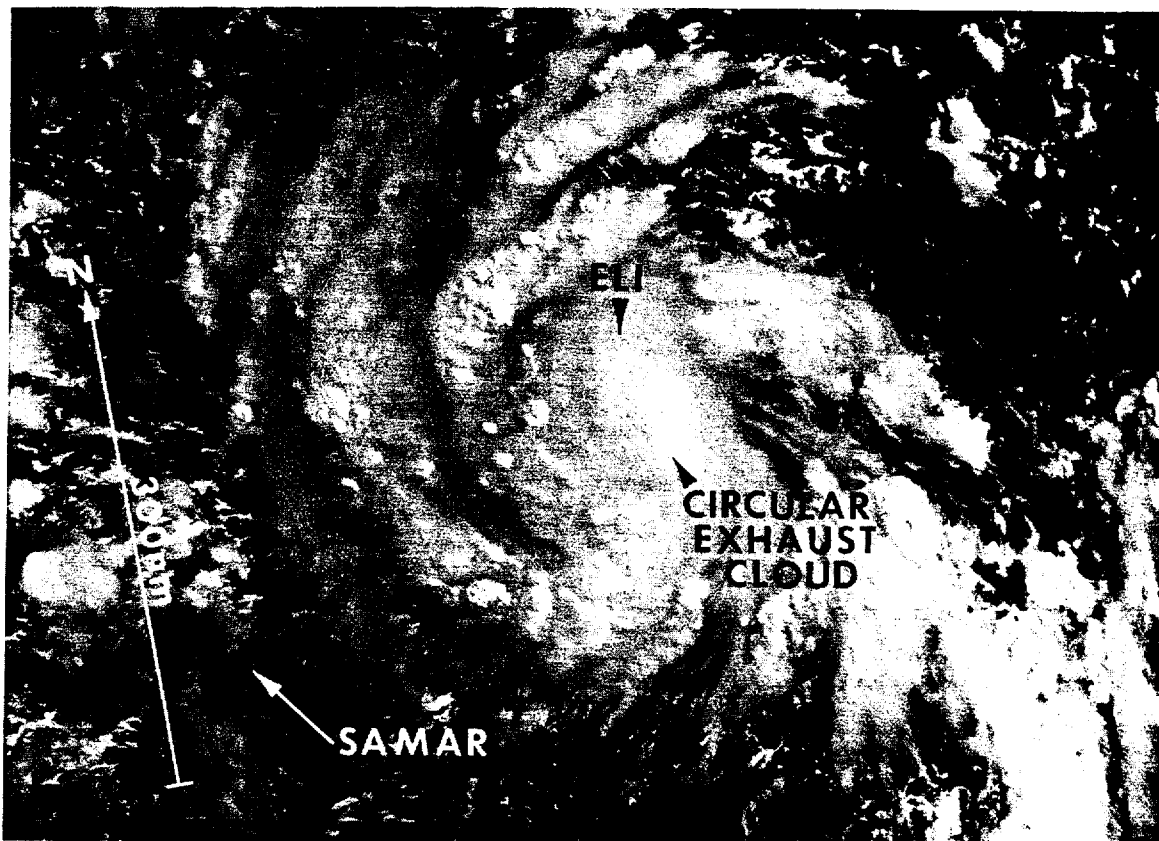
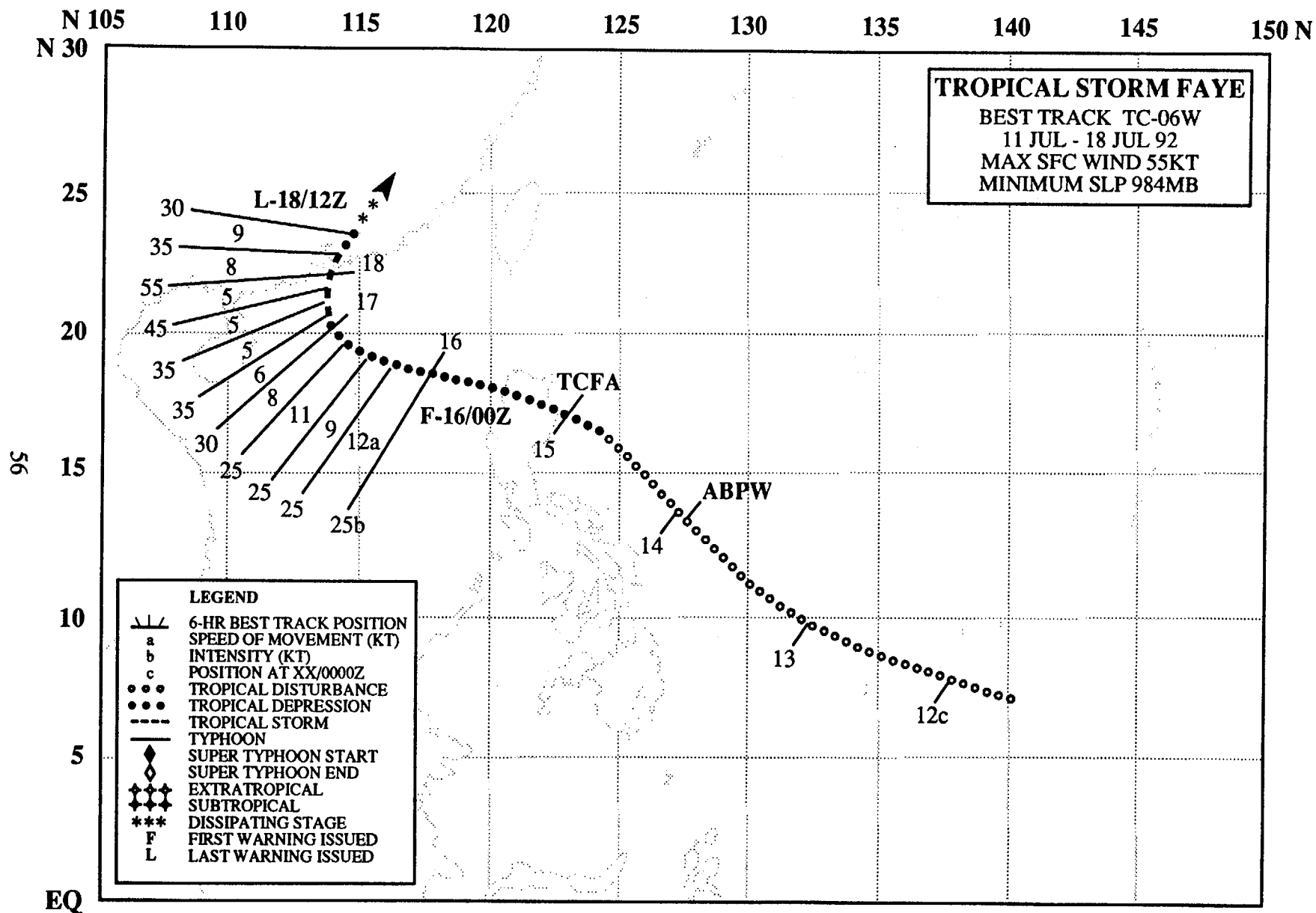


Figure 3-05-1. As Eli intensifies, a circular exhaust cloud (CEC) appears superimposed on the central dense overcast. The low angle of the sun to the east accentuates the cloud-top topography, revealing a concentric, or tree ring-like pattern of gravity waves in the top of the CEC (092354Z July DMSP visual imagery).



## TROPICAL STORM FAYE (06W)

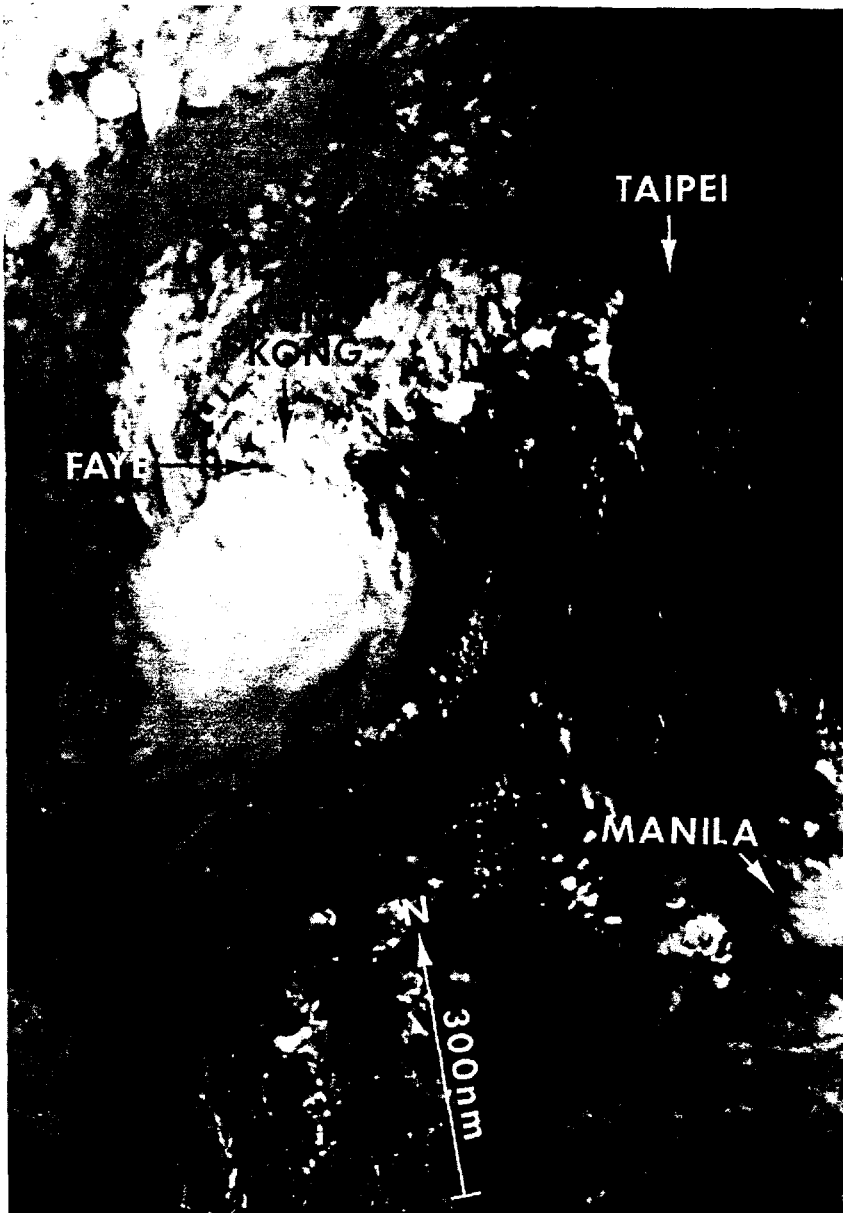
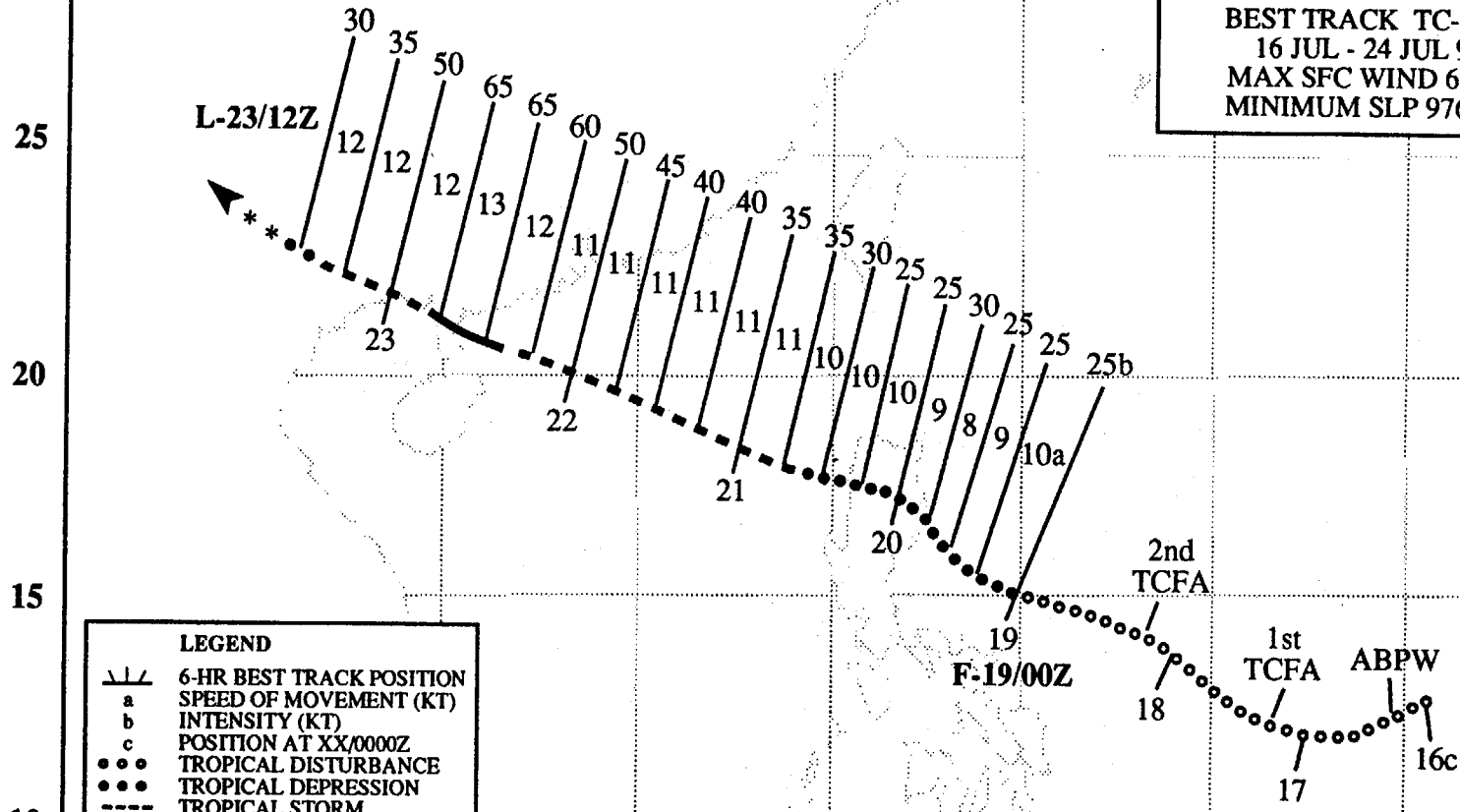


Figure 3-06-1. Tropical Storm Faye's partially exposed low-level circulation center is visible as it moves onshore near Hong Kong (172303Z July NOAA visual imagery).

Faye, the second of three successive tropical cyclones to pass over northern Luzon and intensify in the South China Sea, was first mentioned in the 130600Z July Significant Tropical Weather Advisory after synoptic data in the western Caroline Islands revealed a cyclonic circulation in the low-level wind field. As the circulation crossed the Philippine Sea, its convective organization increased, prompting forecasters to issue a Tropical Cyclone Formation Alert at 150000Z. After the cloud system crossed northern Luzon and the central convection reformed, the first warning was issued at 160000Z. Tropical Depression 06W proceeded west-northwestward until recurving south of Hong Kong on 17 July. At 170600Z, Faye was upgraded to a tropical storm, and shortly thereafter made landfall with an estimated maximum intensity of 55 kt (28 m/sec). Faye proceeded north-northeastward into China and dissipated. The final warning was issued at 181200Z.

E 100 105 110 115 120 125 130 135 140 E  
N 30

**TYPHOON GARY**  
**BEST TRACK TC-07W**  
 16 JUL - 24 JUL 92  
 MAX SFC WIND 65KT  
 MINIMUM SLP 976MB



## TYPHOON GARY (07W)

### I. HIGHLIGHTS

Gary was the last of three consecutive tropical cyclones to cross northern Luzon and intensify in the South China Sea during July. After early difficulties locating the low-level vortex, JTWC correctly predicted that the tropical cyclone would strike the southern coast of China near Hainan Dao. Gary caused widespread damage across southern China.

### II. TRACK AND INTENSITY

Typhoon Gary's track paralleled those of Typhoon Eli (05W) and Tropical Storm Faye (06W). The genesis mechanism for all three was an active monsoon trough, which extended across the Philippine Sea. On 16 July, mention of an area of vigorous convection was included on the daily Significant Tropical Weather Advisory. Within 24 hours, its organization had improved sufficiently to warrant a Tropical Cyclone Formation Alert, which was issued at 170630Z. The Alert was reissued at 180630Z after the broad low-level circulation, containing multiple vortices, failed to consolidate in the presence of increased upper-level shear. At 190000Z, convective organization had improved to the point that the first warning on Tropical Depression 07W was issued. Because the circulation was large and poorly organized, there were large differences in the satellite fix positions as satellite analysts at network sites attempted to pinpoint the location of the low-level circulation center. The cloud system consolidated and became easier to locate by satellite once it crossed the northern Philippines. After being upgraded to tropical storm intensity at 201800Z, Gary tracked west-northwestward across the South China Sea, and later over the Leizhou Peninsula to the north of Hainan Dao. Shortly before land-fall, Gary developed a large, ragged eye (Figure 3-07-1), which prompted its upgrade to typhoon intensity at 221200Z. After reaching an estimated peak intensity of 65 kt (33 m/sec), the typhoon made land-fall and dissipated. Ship reports near Hainan Dao indicated that winds in excess of 30 kt (15 m/sec) persisted overwater until after the cyclone center was well inland, which necessitated additional tropical cyclone warnings until 231200Z.

### III. FORECAST PERFORMANCE

JTWC's track forecasts improved significantly after the low-level circulation center consolidated on 20 July. Initial position errors fell in the 25 nm (45 km) range in contrast to those a day earlier on 19 July, which were in the 125 nm (230 km) range. Early on, JTWC correctly predicted Gary's west-northwestward track across the South China Sea, just as Eli (05W) and Faye (06W) had done less than two weeks earlier.

### IV. IMPACT

News reports indicated that Typhoon Gary's passage over southern China resulted in the deaths of 26 people, and injuries to another 63. The southern provinces of Guangdong and Guangxi suffered extensive flood and wind damage with losses estimated at \$148 million (US).

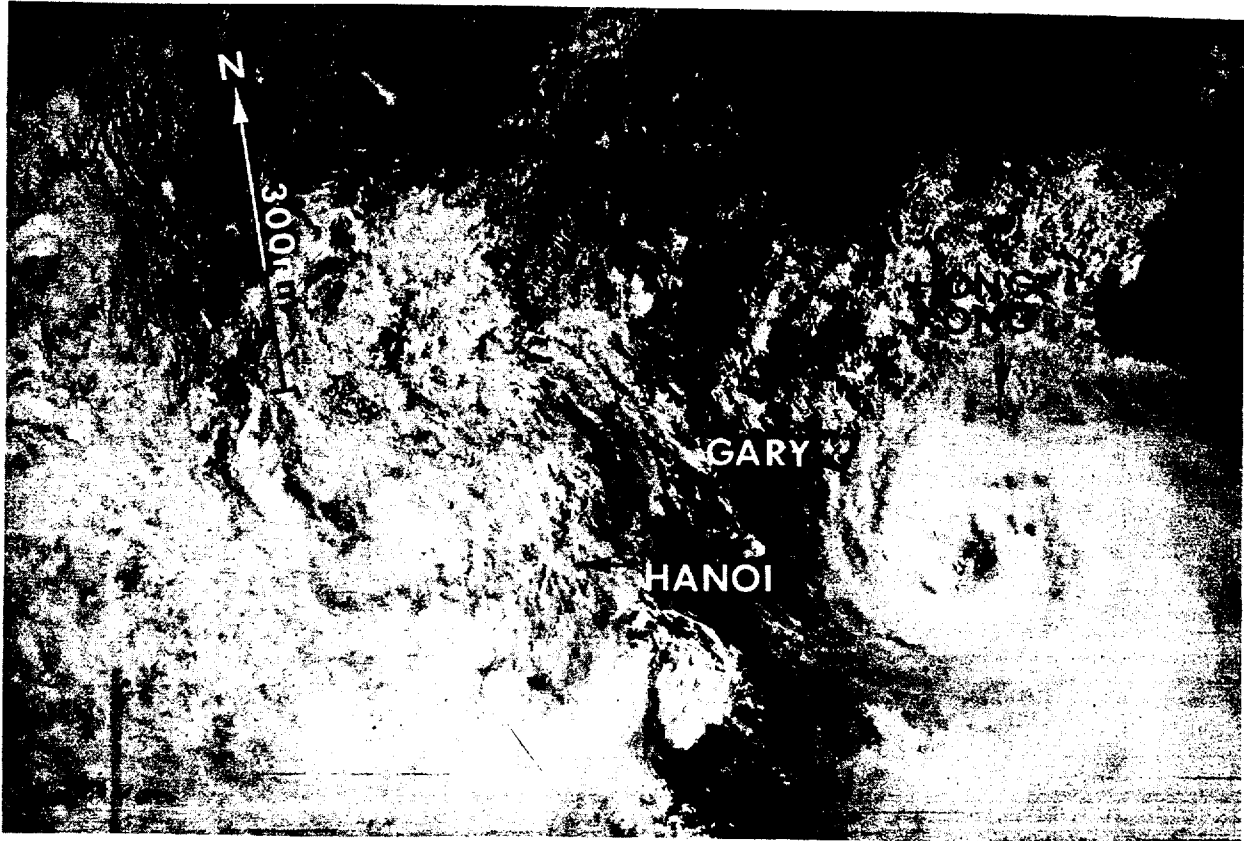
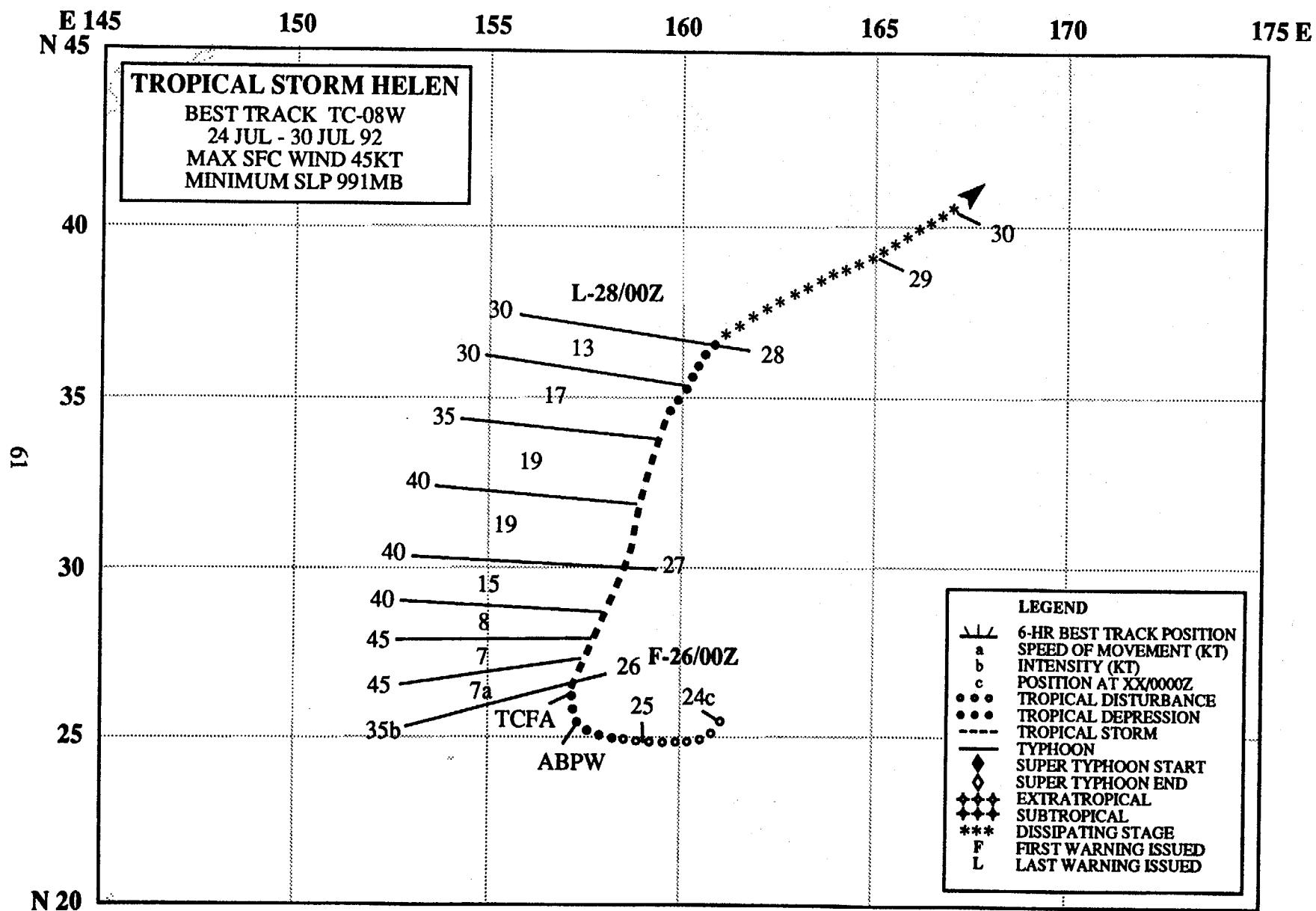


Figure 3-07-1. Gary with a large, ragged eye is intensifying as it approaches the southern coast of China (220200Z July DMSP visual imagery).



## TROPICAL STORM HELEN (08W)

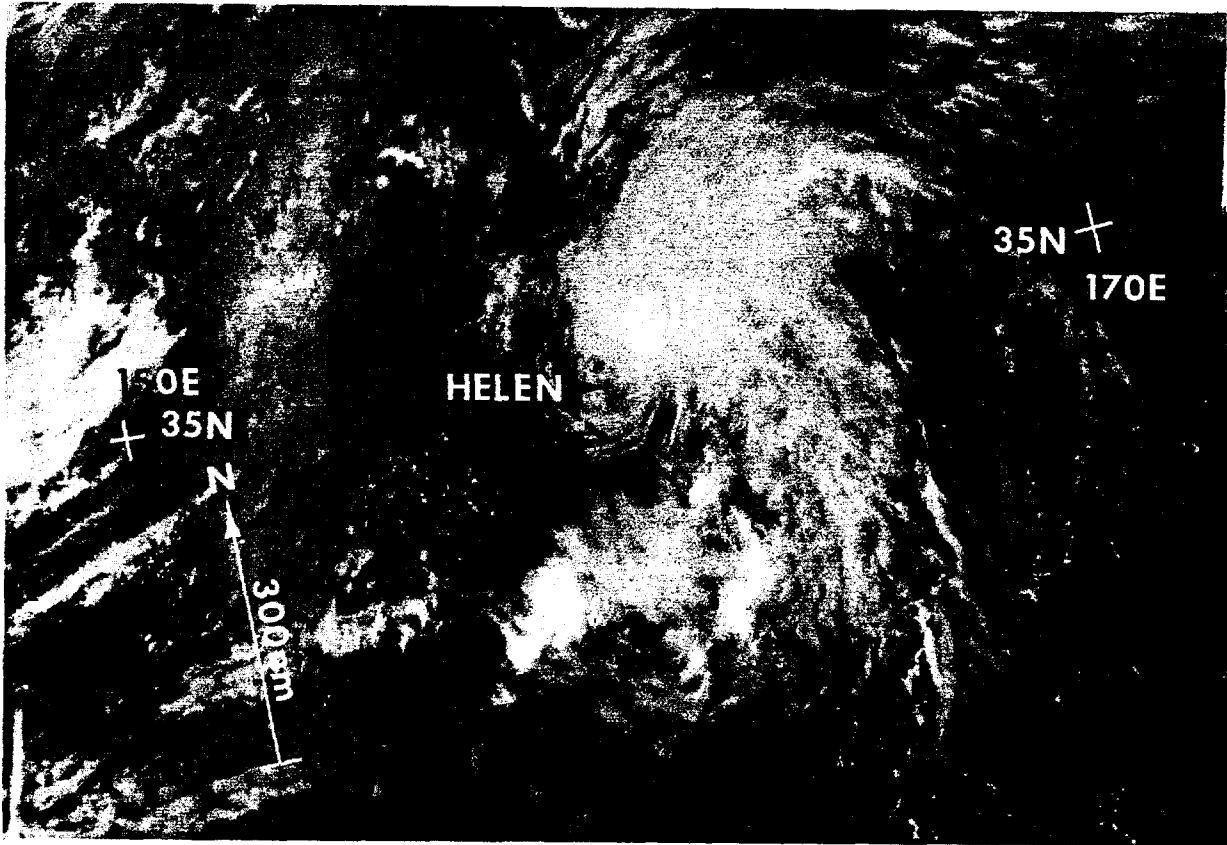
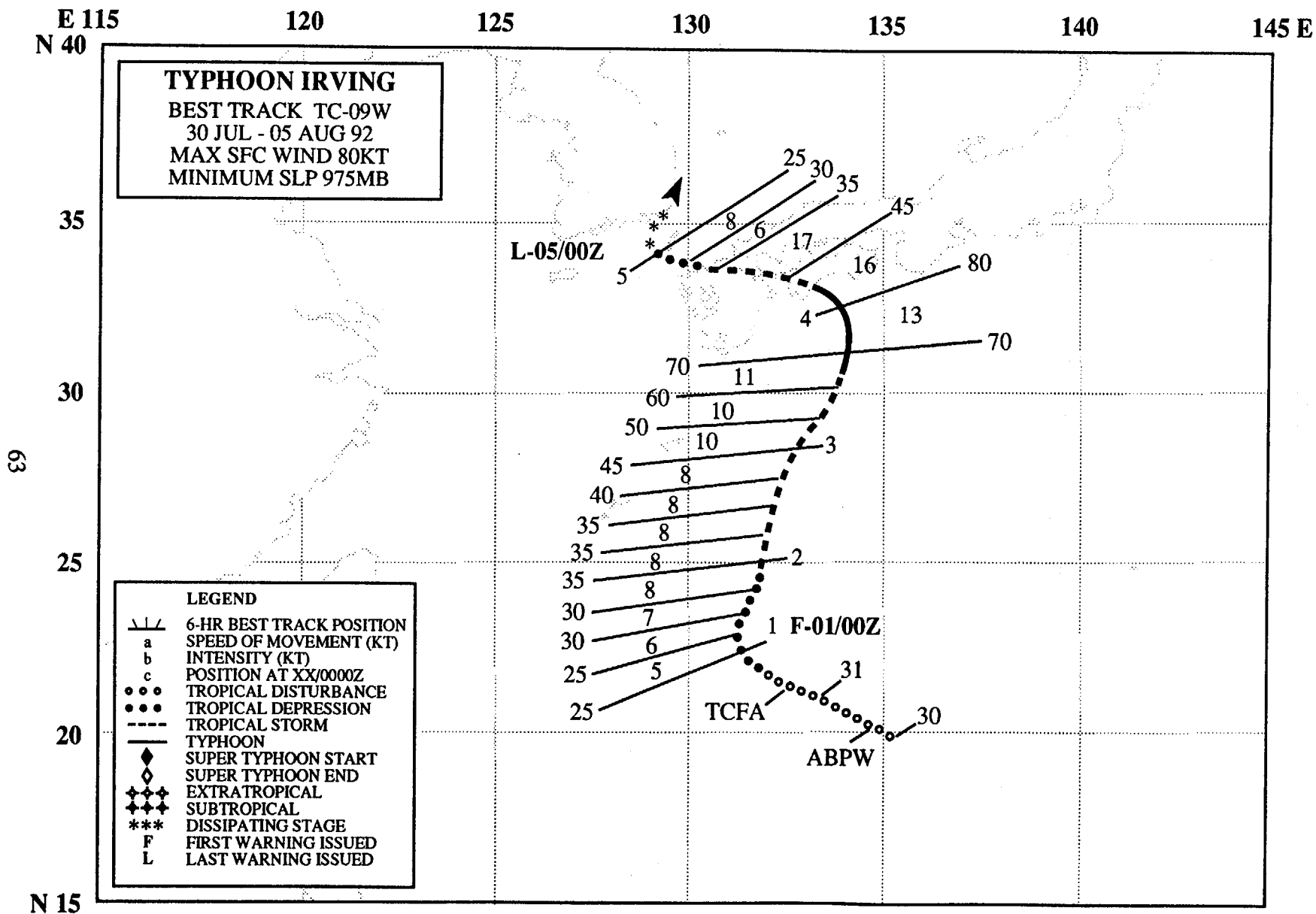


Figure 3-08-1. As Helen weakens, the low-level cloudiness defining its circulation center appears to the south-southwest of the central cloud mass (271401Z July NOAA visual imagery).

The fourth of five significant tropical cyclones to develop in July, Helen intensified from a Tropical Upper Tropospheric Trough (TUTT)-induced low-level circulation. The initial Significant Tropical Weather Advisory issued at 250600Z was reissued at 251900Z to include mention of a persistent area of deep convection. At 252300Z, JTWC issued a Tropical Cyclone Formation Alert when the system showed a steady increase in low-level cloud organization. The first warning followed quickly at 260000Z, based on visual satellite observations of curved low-level cloud lines associated with this midlevel tropical cyclone and satellite Dvorak intensity estimates of 25 kt (13 m/sec). Helen continued to intensify as it slowly tracked to the north and reached its peak intensity of 45 kt (23 m/sec) at 260600Z. The tropical storm began to weaken as it gained latitude and moved into a region of cooler sea-surface temperatures. The final warning on this system was issued at 280000Z when satellite imagery indicated that Helen no longer maintained any persistent central convection.





## TYPHOON IRVING (09W)

### I. HIGHLIGHTS

The last of five significant tropical cyclones to develop in July, Irving was the first of two successive typhoons to affect Southwest Japan. It formed at the eastern end of the monsoon trough where several low-level vorticity centers were embedded in a broad area of poorly organized convection, and slowly intensified. Initially, track forecasts suffered due to a difficulty in distinguishing a clear-cut, low-level circulation center. Once an accurate track history was established and the Joint Typhoon Warning Center committed to a north-oriented track followed by westward motion due to the expected reestablishment of the mid-level subtropical ridge north of Irving, forecast errors were significantly reduced. Intensity estimates based solely on satellite imagery proved to be too low as all forecast agencies peaked Irving as a tropical storm. Post-storm analysis has revealed enough synoptic data to justify upgrading Irving to a typhoon.

### II. TRACK AND INTENSITY

Initially, synoptic and satellite data indicating a definite, albeit weak, low-level cyclonic circulation within the monsoon trough that extended from the South China Sea to the central Philippine Sea. This circulation was mentioned on the 300600Z July Significant Tropical Weather Advisory. While multiple low-level vorticity centers were present at this early stage of development, JTWC focused on the circulation near a major flare-up of convection occurring in the southwestern portion of the tropical disturbance. The detection of curved low-level cloud lines on the visual satellite imagery resulted in JTWC issuing a Tropical Cyclone Formation Alert at 310800Z. By 01 August at 0000Z, the cloud organization had improved sufficiently to classify this system as a tropical depression, and the first warning was issued. A short time after this warning, a weather reconnaissance aircraft from the Tropical Motion Cyclone Experiment (TCM-92) explored the structure of the tropical depression, and determined that the primary low-level circulation was most probably situated 120 nm (220 km) further to the north than inferred from the satellite data. The circulation proceeded slowly northward over the next two days and gradually intensified. This slow northward motion was attributed to the tropical cyclone being situated near the western periphery of the subtropical ridge. At 020000Z, the amount of centralized deep convection had increased, prompting forecasters to upgrade the tropical depression to a tropical storm.

From the standpoint of satellite intensity estimates, Irving appeared to reach its peak intensity of 55 kt (28 m/sec) at 031200Z based on the curvature of the convection. However, synoptic data indicated that Irving continued to intensify, and attained a peak intensity of 80 kt (41 m/sec) at 040000Z. The surface pressure pattern and key wind reports are depicted in Figure 3-09-1. The figure shows the tight pressure gradient that existed to the north of the typhoon. The visual imagery (Figure 3-09-2) nearest the time of the synoptic data shows Irving with an elliptic eye that was approximately 100 nm (185 km) in diameter. With the ridge established to the north, the tropical cyclone began to track west-northwestward. Upon landfall over southwestern Shikoku, Irving turned sharply to the west, rapidly weakened, and later, dissipated over the Korea Strait near Pusan, Korea.

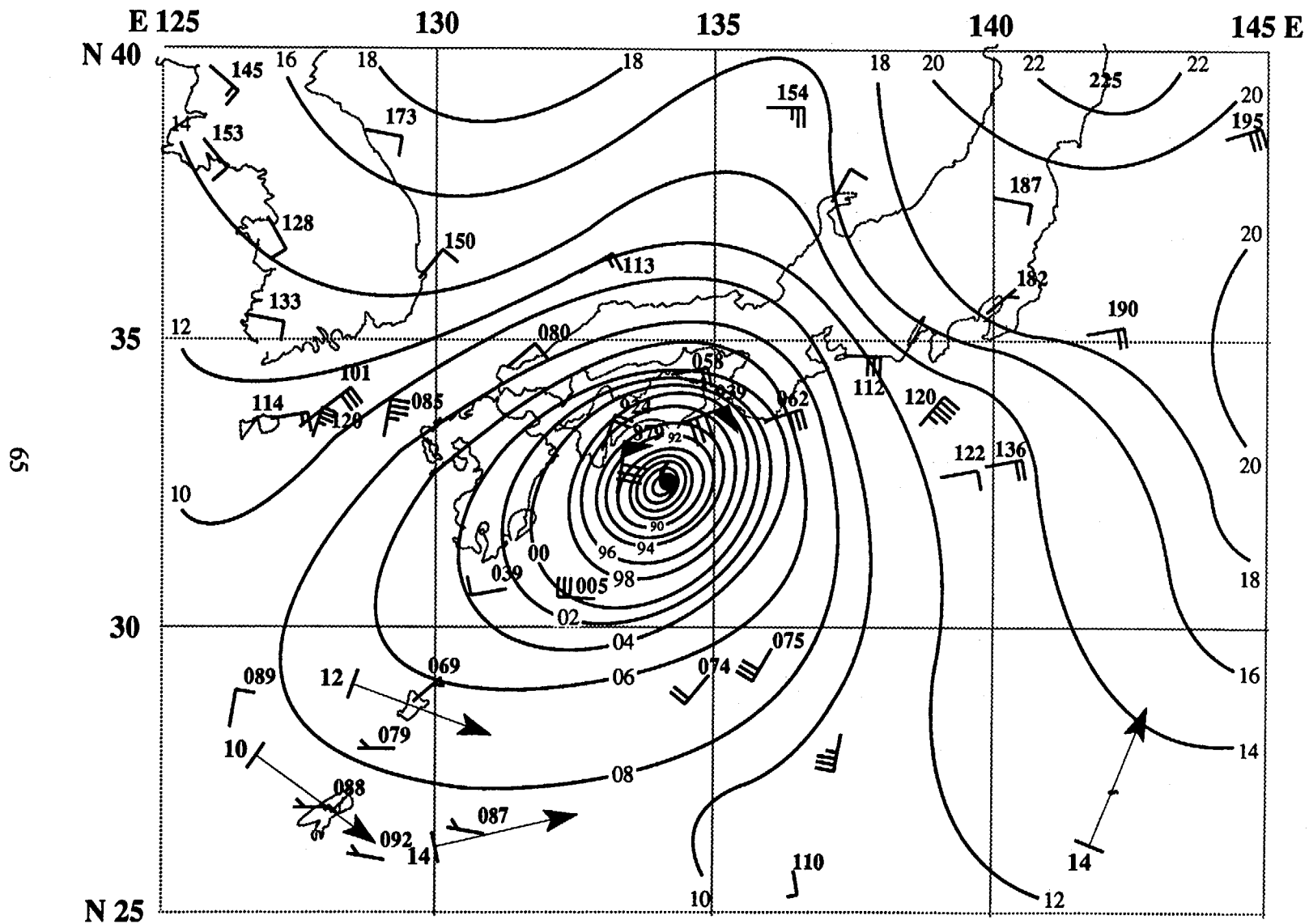


Figure 3-09-1. Synoptic data and analysis for 040000Z August reveals the tight pressure gradient to the north of Irving. The two 80 kt (41 m/sec) reports are located under the wall cloud. (The arrows at the bottom of the analysis indicate gradient-level wind reports.)

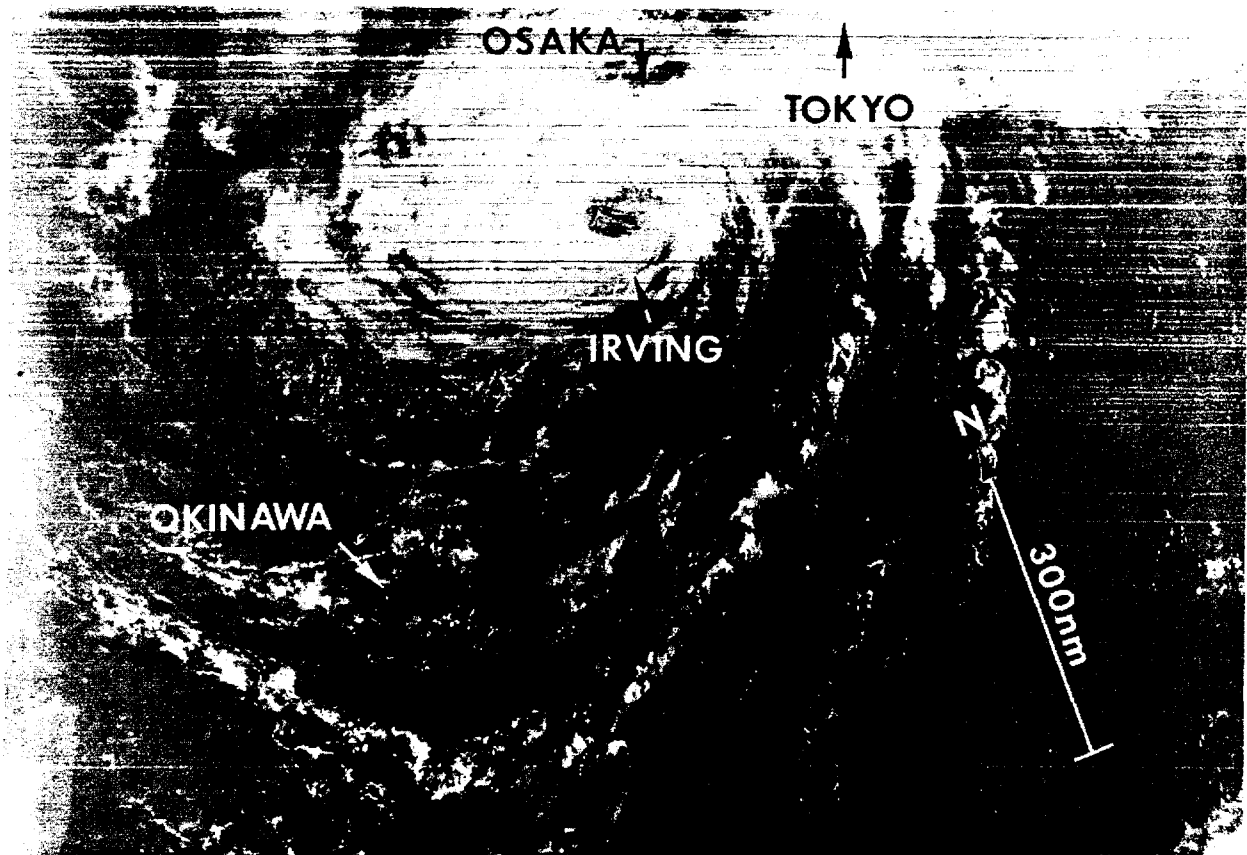


Figure 3-09-2. The satellite data, corresponding to the synoptic analysis in Figure 3-09-1, shows Irving with a large eye just before making landfall on Shikoku (040015Z August DMSP visual imagery).

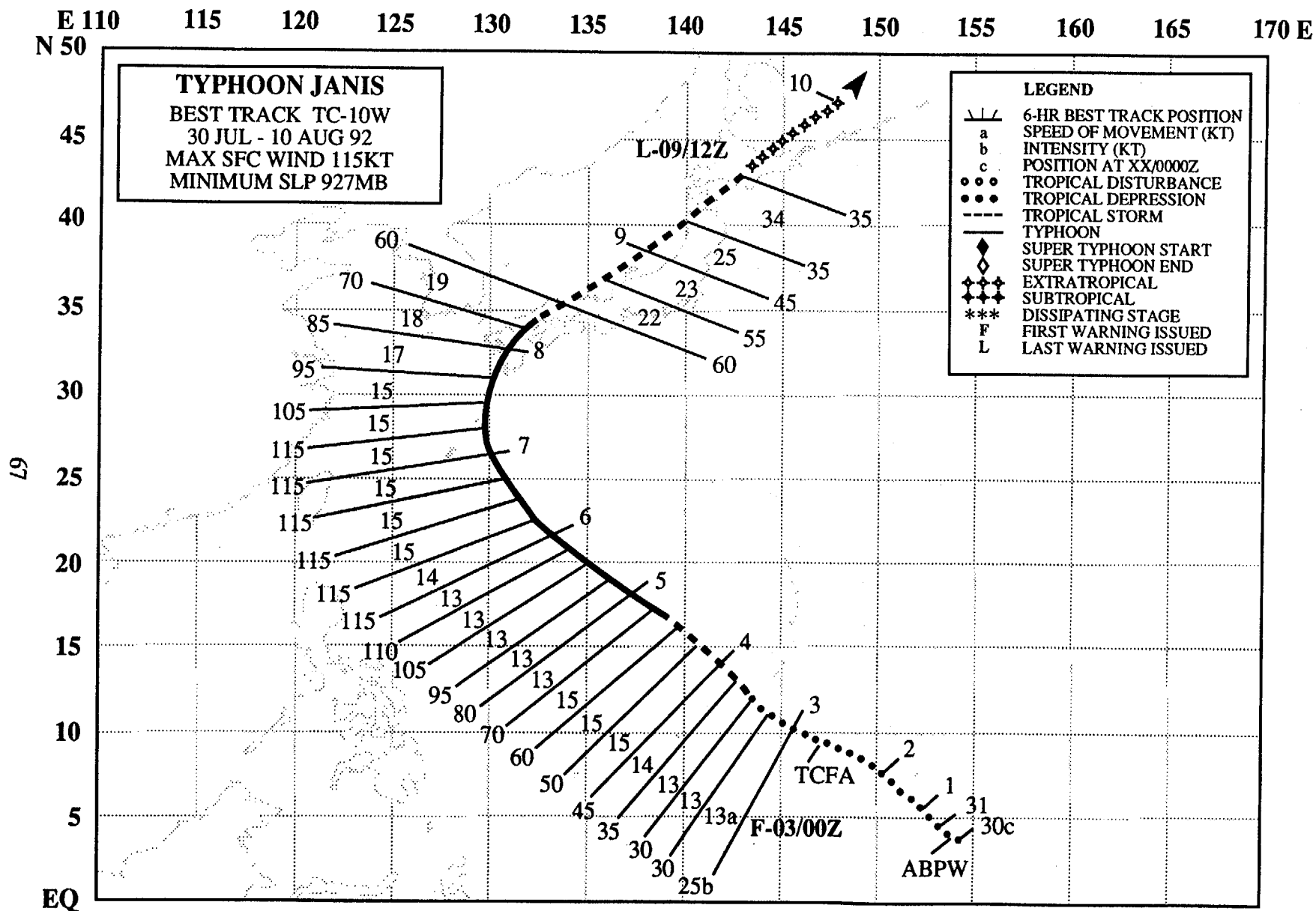
### III. FORECAST PERFORMANCE

Forecasting for Irving proved to be quite challenging as climatological and numerical model guidance were in almost total disagreement. To complicate the forecast difficulties, problems with locating the low-level center during the first five warnings led to four relocated warnings. Once the persistent northward motion was established, JTWC placed a heavier reliance on climatological and statistical based models. Then, when Irving was approaching Japan, predictions based on the NOGAPS model provided correct guidance. In retrospect, the Japanese Typhoon Model (JTYM), although biased right-of-track, provided accurate guidance for timing and direction of major track directional changes.

With regard to intensity forecasts, JTWC did not anticipate the further drop in central pressure of the tropical cyclone and building of the pressure gradient to the north as Irving approached Japan, which resulted in underforecasting the winds.

### IV. IMPACT

Although some observations from Japan were in excess of 60 kt (31 m/sec) and orographically induced rainfall was heavy, there were no reports of significant damage received.



## **TYPHOON JANIS (10W)**

### **I. HIGHLIGHTS**

Four days after Irving (09W) hammered Shukoku, Janis slammed into Kyushu. Janis began near Pohnpei in the Caroline Islands, took a northwestward track threatening Okinawa, then recurved, passed over Kyushu, and skirted the western coast of Honshu before transitioning to an extratropical low over Hokkaido.

### **II. TRACK AND INTENSITY**

The tropical disturbance, that matured into Janis, formed near Pohnpei in the eastern Caroline Islands, and was first mentioned in the 300600Z July Significant Tropical Weather Advisory. Increased convective development led to the issuance of a Tropical Cyclone Formation Alert at 022130Z August. Intensification continued through the early morning hours, and at 030000Z, JTWC issued the first warning on Tropical Depression 10W. As the depression moved past Guam, it brought winds gusting to 30 kt (15 m/sec) and 2.5 inches (64 mm) of rain in 24 hours to the island, but caused no major damage.

Later that day, at 031439Z, aircraft reconnaissance assigned to the TCM-92 experiment explored the tropical depression and provided a center fix with a minimum 700 mb pressure height of 3081 m, which supported 30 kt (15 m/sec) at the surface. Moving into the Philippine Sea, the depression organized further and was upgraded to a tropical storm at 031800Z and to a typhoon 24 hours later. Janis reached a peak intensity of 115 kt (59 m/sec) at 060000Z, where it posed a major threat to Okinawa (Figure 3-10-1). Fortunately, the typhoon did not directly hit the island, but passed 90 nm (165 km) to the east. On Okinawa, Kadena AB (WMO 47931) reported maximum winds of 30 gusting to 50 kt (15 G 26 m/sec), the Marine Corps Air Station (WMO 47933) at Futenma observed peak winds of 36 gusting to 53 kt (19 G 27 m/sec), and the peak at Naha (WMO 47936) was 34 gusting to 55 kt (18 G 28 m/sec).

Passing near the airport on Amami-O-Shima (WMO 47872) which reported maximum winds of 69 gusting to 94 kt (36 G 48 m/sec), the typhoon began to weaken, recurved, and accelerated toward Kyushu. Over Kyushu, land interaction further weakened Janis to tropical storm intensity at 081500Z. As Janis passed 60 nm (110 km) east-southeast of Sasebo with an estimated intensity of 85 kt (44 m/sec), the base observed maximum winds of 28 gusting to 50 kt (14 G 26 m/sec). The tropical storm moved to the northeast, paralleling the western coast of Honshu. At 091200Z, Janis transitioned into an extratropical low over Hokkaido.

### **III. FORECAST PERFORMANCE**

JTWC correctly forecast the recurvature path of Typhoon Janis. Overall, mean track forecast errors were 92, 182, and 336 nm (170, 337 and 620 km) for 24, 48, and 72 hours, respectively. The largest 72-hour mean position forecast errors occurred after recurvature and were primarily due to the rapid acceleration of Janis to speeds over 30 kt (55 km/hr).

JTWC forecast the intensity trend and period of rapid intensification well. However, with regard to the peak intensity, a procedural difference concerning the application of the Dvorak enhanced infrared technique eye adjustment factor to digital high resolution TIROS-N polar orbiting satellite data led to an overestimation of the raw intensity input to the warning. The analysis procedure was reviewed and adjusted to use the average of the warmest pixels within the eye, instead of the single warmest individual pixel, before determining the eye adjustment factor. This change more closely paralleled the val-

ues derived from the geostationary data , and resulted in the peak intensity being reduced from 125 to 115 kt (64 to 59 m/sec). The largest 72-hour mean intensity forecast errors occurred after recurvature when the system weakened more rapidly than anticipated.

#### IV. IMPACT

As Janis passed to the east of Taiwan, one fisherman was killed when 26 foot (8 m) waves sank five fishing boats. Only minor damage was reported when the typhoon passed just to the east of Okinawa. The passage of Janis over Kyushu resulted in the death of one person and injuries to at least 25 others. High winds and torrential rains caused the temporary loss of electricity to over 250,000 homes, and disrupted road, rail and air travel in Southwestern Japan.

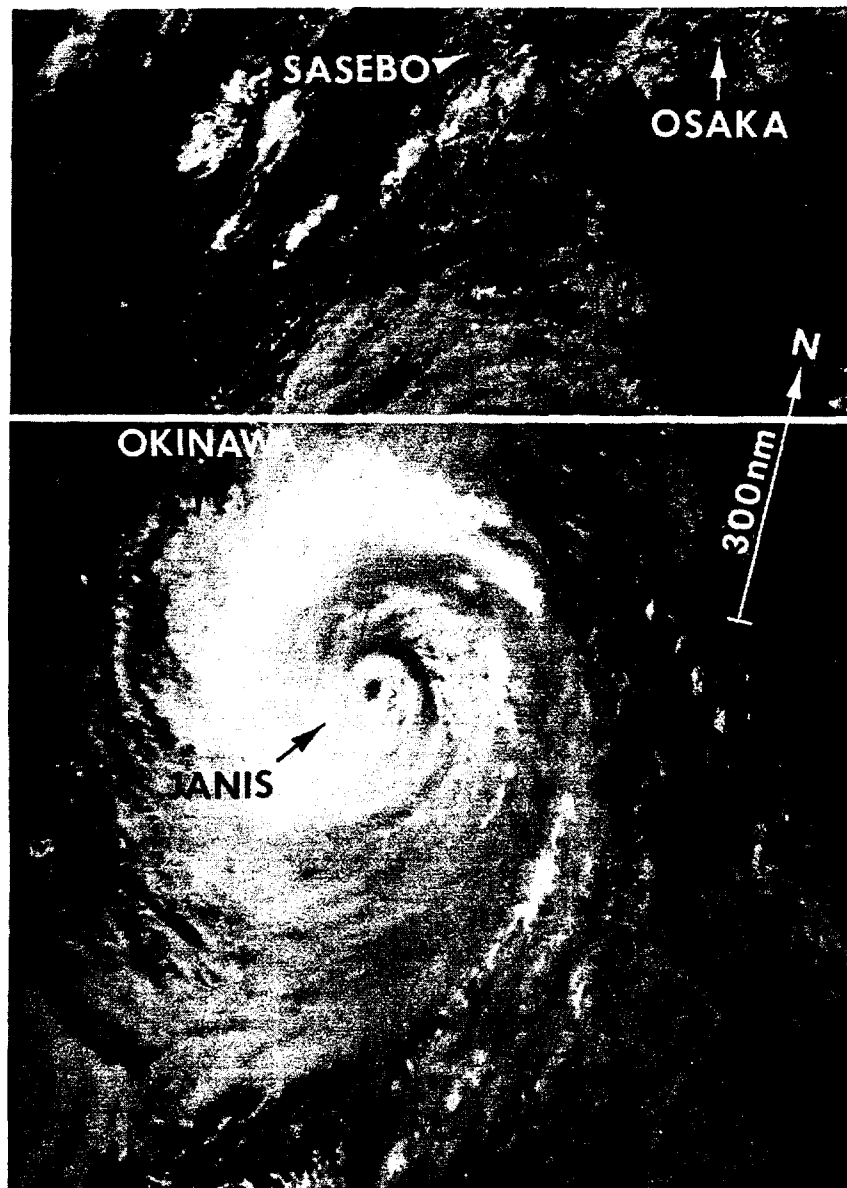
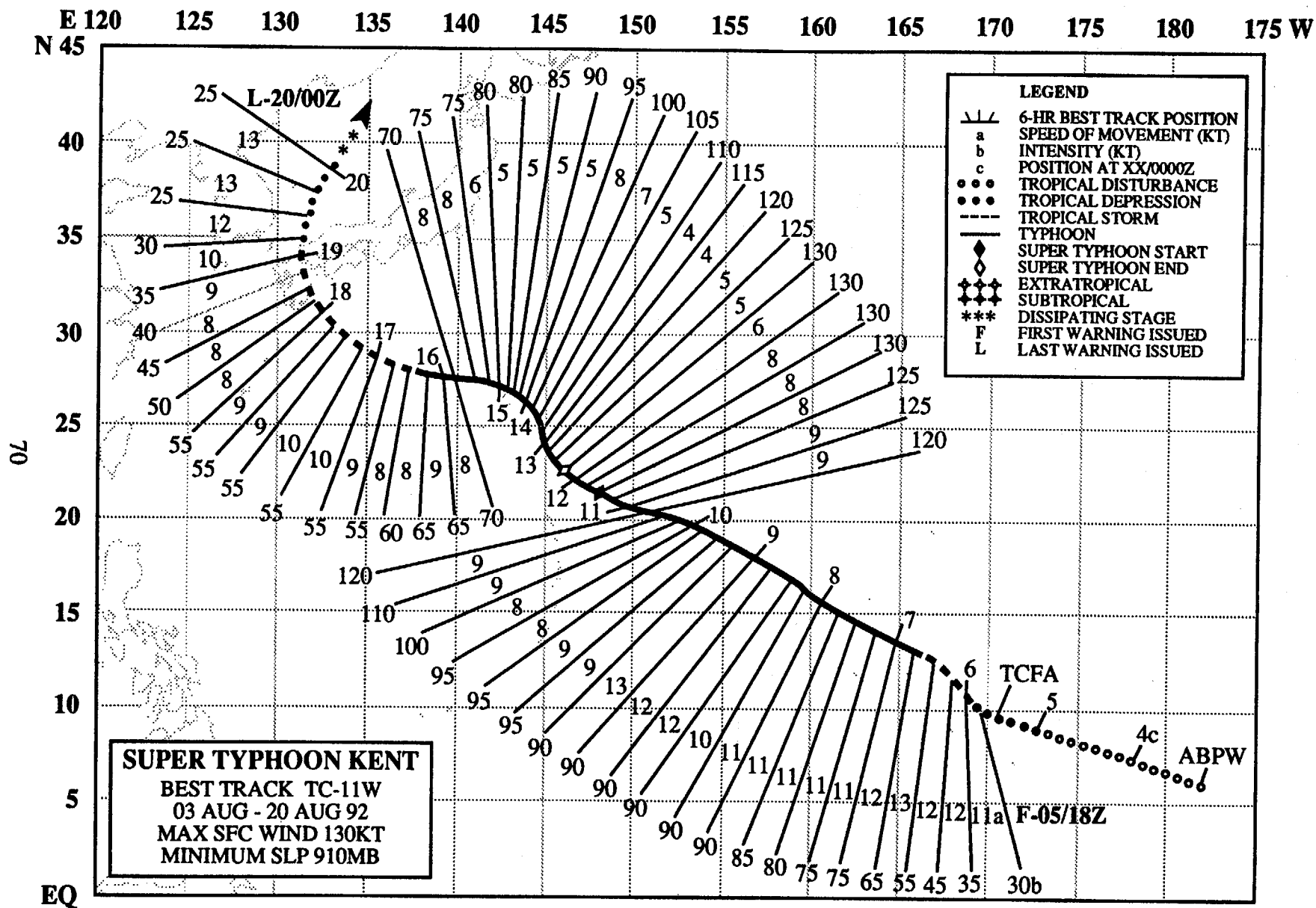


Figure 3-10-1. Typhoon Janis at peak intensity bears down on Okinawa (060533Z August NOAA visual imagery).





## **SUPER TYPHOON KENT (11W)**

### **I. HIGHLIGHTS**

The second of eight tropical cyclones to develop in August, Kent became the first super typhoon of 1992. During the trek toward Japan, it underwent binary interaction with Tropical Storm Lois (12W). Requiring a total of 58 warnings, Kent was second only to Super Typhoon Gay (31W) for the total number of warnings and longevity for the western North Pacific in 1992.

### **II. TRACK AND INTENSITY**

As Janis (10W) intensified south of Guam, the tropical disturbance that later became Kent developed east of the international date line. Its persistent convection was first mentioned on the 030600Z August Significant Tropical Weather Advisory. An increase in the amount and organization of the disturbance's deep convection prompted JTWC to issue a Tropical Cyclone Formation Alert at 051500Z. Early intensification was rather rapid. The first warning was issued at 051800Z with an upgrade to tropical storm intensity at 060000Z, and to typhoon intensity at 070000Z. Then the rate of intensification slowed. On 8 August, increased vertical wind shear associated with the passage of a mid-level trough to the north resulted in a reduction in size of Kent's central dense overcast (CDO). Although intensification was arrested, a small core of persistent central convection remained. As the trough passed by, the reappearance of an eye confirmed that intensification was once again underway. At 111200Z, Kent reached super typhoon intensity (Figure 3-11-1).

Under the influence of a subtropical ridge located to the north, the super typhoon continued to move west-northwestward until a short wave trough moved across Honshu on 13 August. Kent, weakened, slowed and its track became more northerly in response to the weakness in the subtropical ridge. Then, the trough passed by and the typhoon, which was weakening due to increasing upper-level winds, headed for Honshu. On 16 August, Kent became involved in a binary interaction with Tropical Storm Lois (12W), which had formed two days earlier. As a consequence, Kent changed its course for Kyushu. By 18 August, the binary interaction between the tropical cyclones had ceased, and Kent was approaching recurvature. After landfall, interaction with the mountainous terrain of Kyushu, along with increased upper-level wind shear, quickly weakened Kent. At 191200Z, the tropical cyclone was downgraded to a tropical depression when it became evident that all deep convection had been completely sheared by upper-level flow. The final warning on Kent was issued on 200000Z.

### **III. FORECAST PERFORMANCE**

Overall JTWC track forecasting was better than average with mean errors of 70, 140, and 235 nm (130, 265, and 435 km) for 24, 48 and 72 hours, respectively, and consistently better than CLIPER's guidance. General guidance provided by the forecast aids for Kent was excellent until the binary interaction with Tropical Storm Lois (12W) commenced and premature recurvature was suggested. Once the binary interaction between both storms ended, however, all forecast aids correctly predicted Kent's track across Kyushu and into the Sea of Japan. Overall JTWC intensity forecasts were handled well with the exception of a number of 72-hours forecasts, which remained 20 to 40 kt (37 to 74 m/sec) too high for three days after Kent's winds reached their maximum.

#### IV. IMPACT

On 18 August, Kent's high winds and torrential rains struck Kyushu resulting in at least four deaths, disruption of air and ground transportation, and numerous localized power outages.

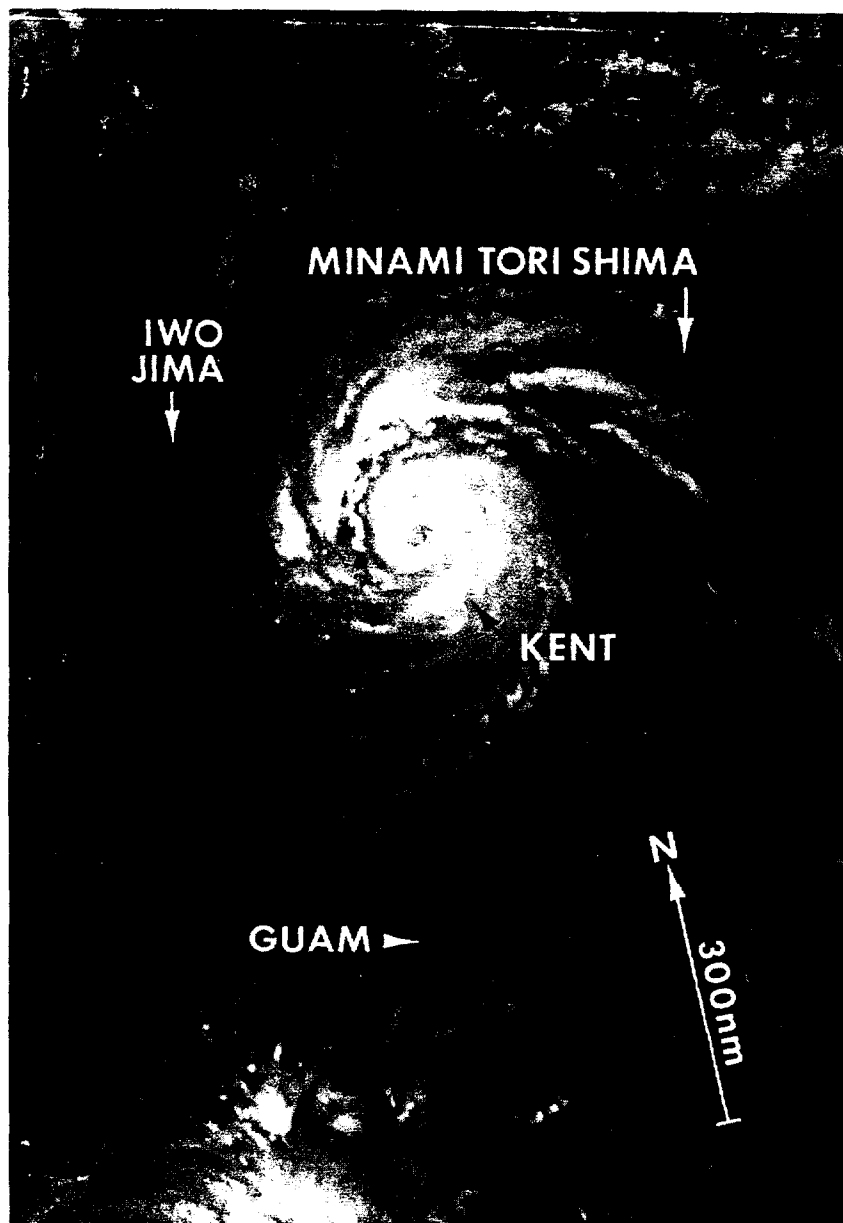


Figure 3-11-1. Kent at super typhoon intensity passes just to the north of the Mariana Islands (112325Z August DMSP visual imagery).

E 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180

N 55

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EQ

# **TROPICAL STORM LOIS**

BEST TRACK TC-12W

13 AUG - 22 AUG 92

MAX SFC WIND 40KT

MINIMUM SLP 994MB

L-22/00Z

F-15/06Z

TCFA

ABFW

## **LEGEND**

- 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- ... TROPICAL DISTURBANCE
- ... TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

73

## TROPICAL STORM LOIS (12W)

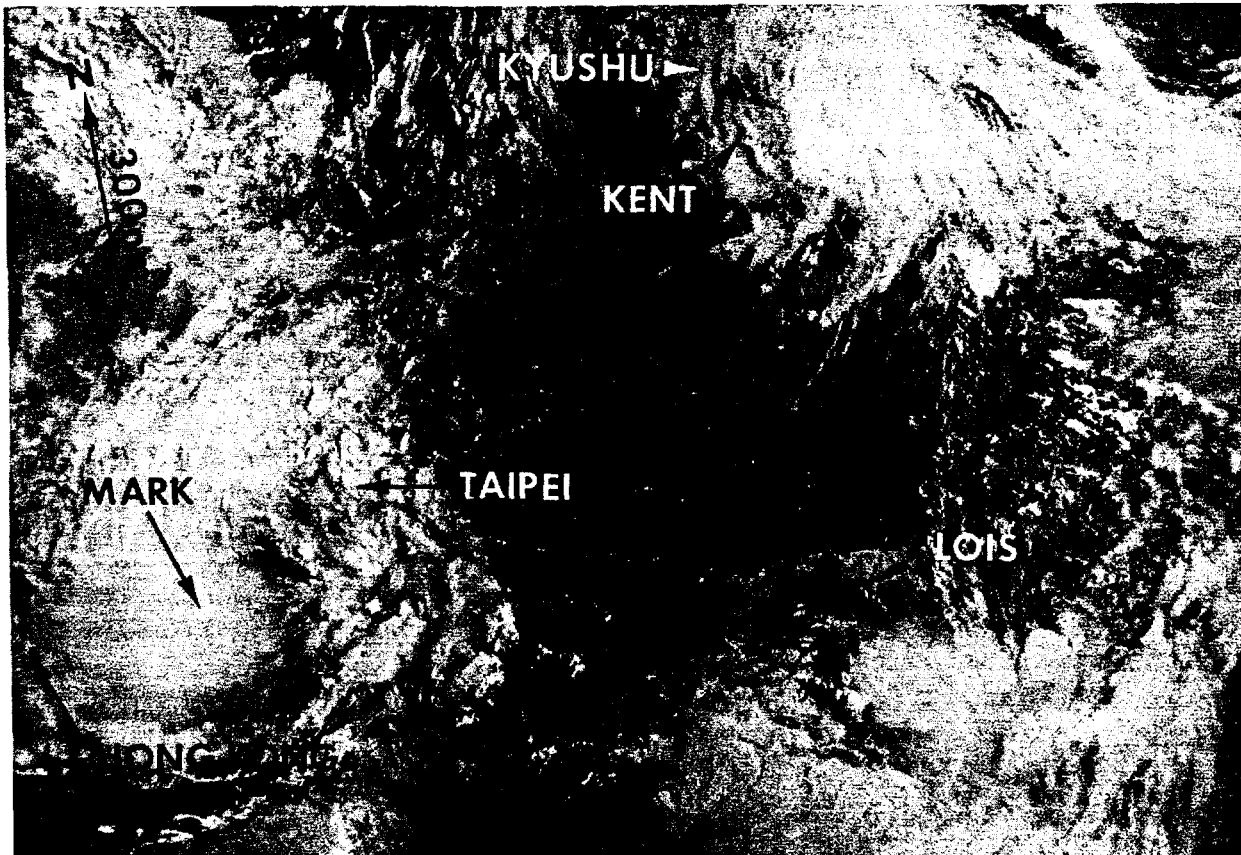
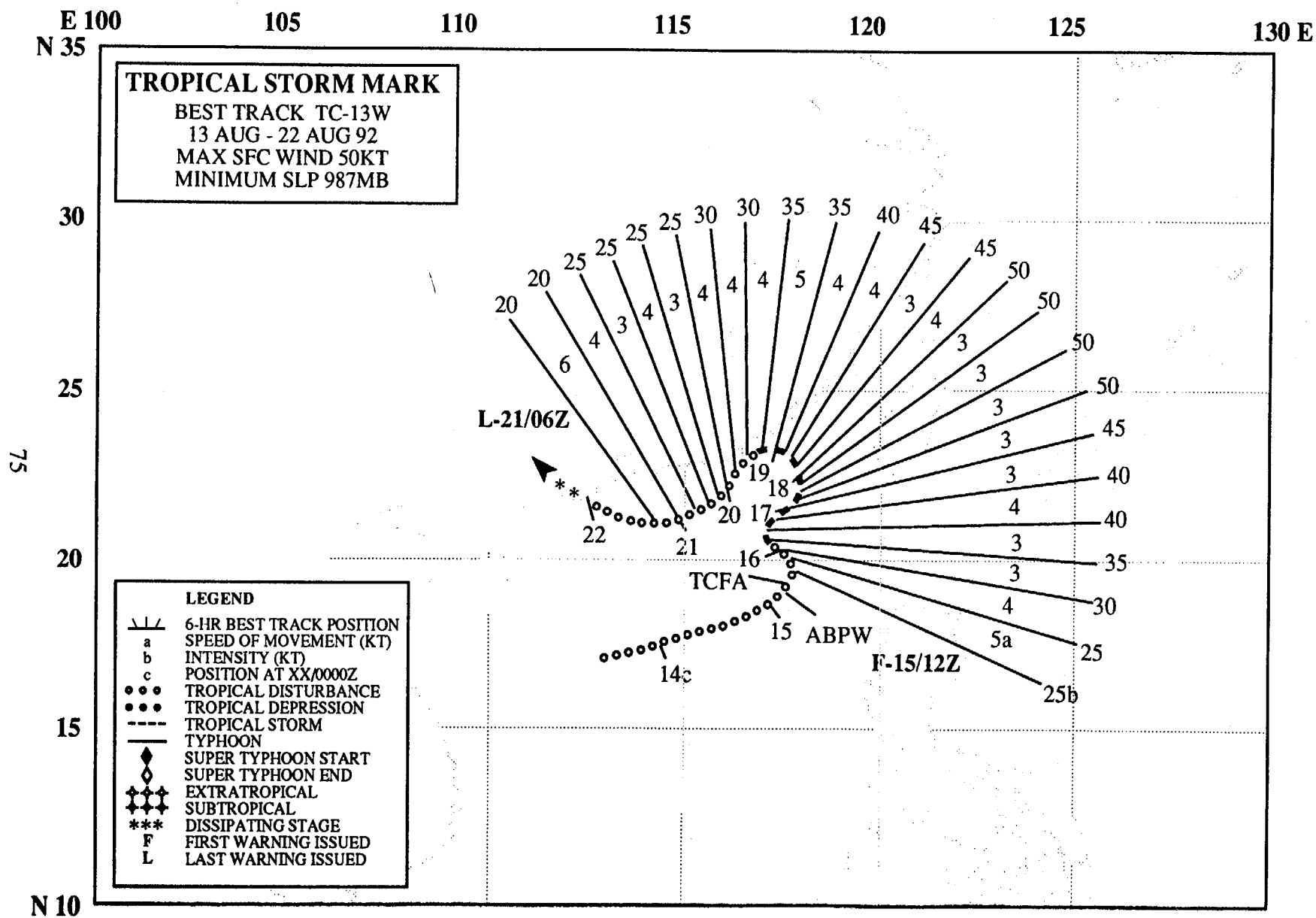


Figure 3-12-1. The partially exposed low-level circulation of Lois is visible to the south of Kent (11W) which is heading for Kyushu. To the west, Mark (13W) is churning up the South China Sea (172325Z August NOAA visual imagery).

Lois, one of only two tropical cyclones in 1992 which had a persistent eastward component of motion during its period of warning, bedeviled JTWC forecasters by consistently moving opposite of the climatologically expected track. During its lifetime, the low-level center of Tropical Storm Lois remained partially exposed, and the system failed to intensify beyond 40 kt (21 m/sec). The apparent binary interaction from 16 to 18 August with Kent (11W) altered Lois' motion and further contributed track forecasting problems. During this period of interaction, the tendency for the NOGAPS to merge nearby tropical cyclones into a single large vortex effectively rendered the model's guidance useless. After escaping the binary interaction, Lois accelerated northeastward and dissipated over colder water. The final warning was issued at 220000Z.



## TROPICAL STORM MARK (13W)

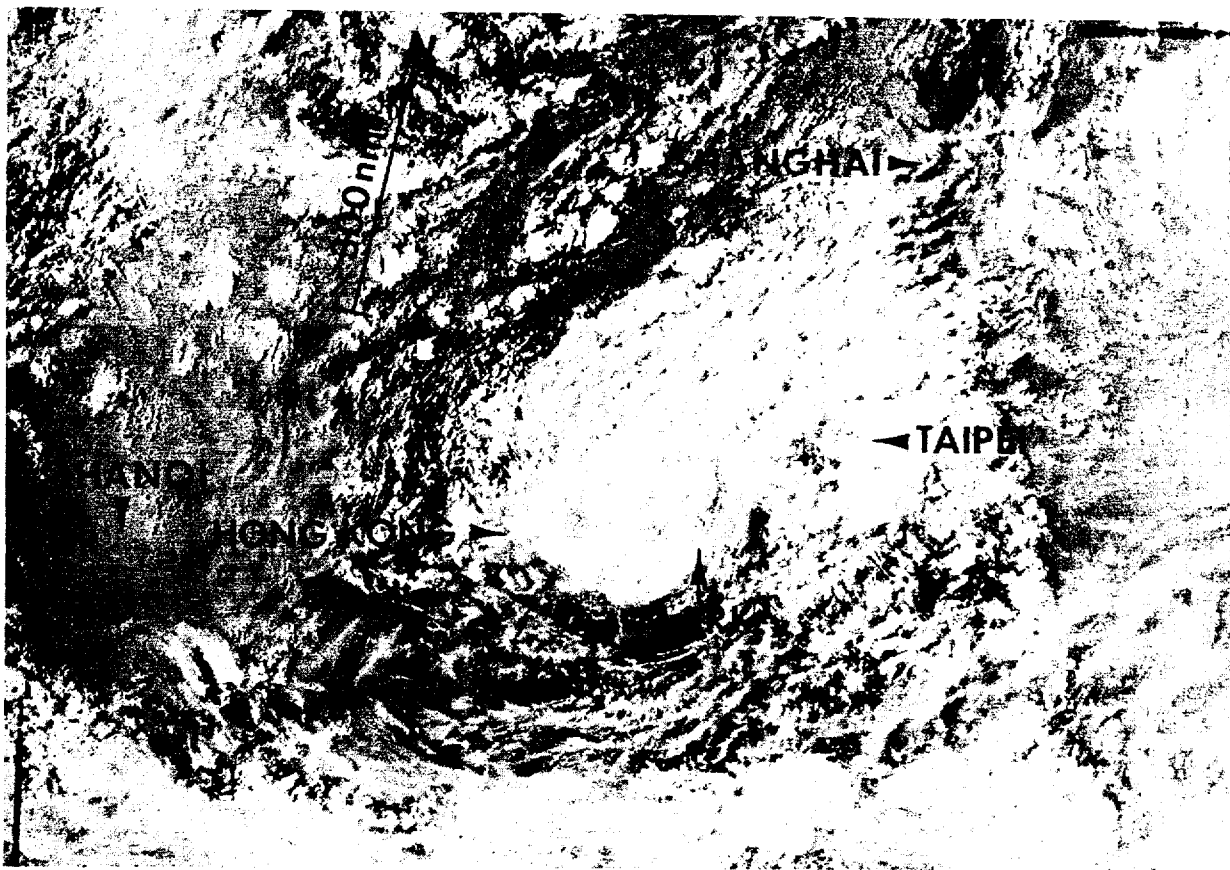
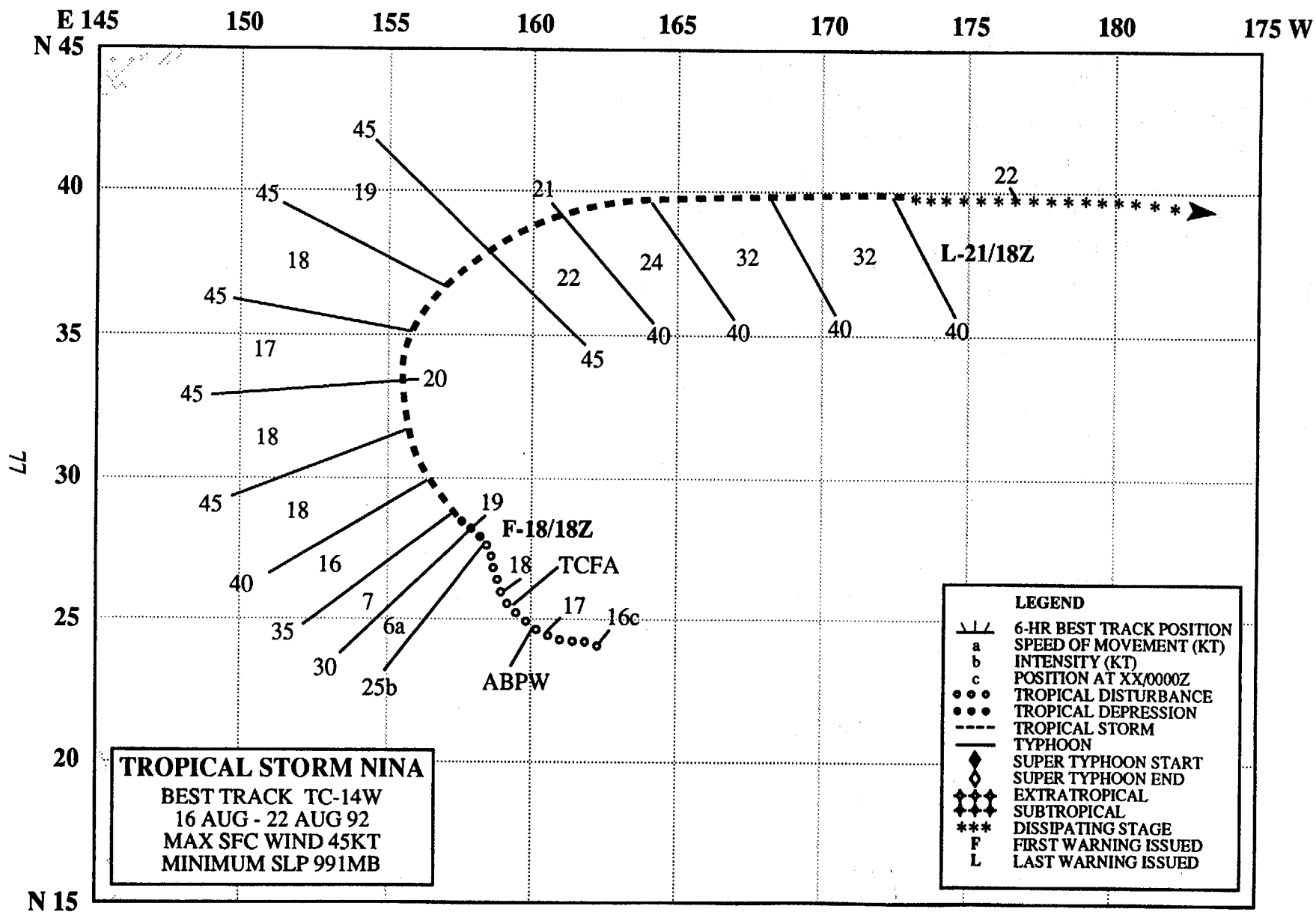


Figure 3-13-1. Mark moves along the southern coast of China (180906Z August DMSP visual imagery).

Mark was part of the three storm outbreak with Kent (11W), Lois (12W), and later, a four storm outbreak when Nina (14W) formed. On 15 August, Mark's genesis in the South China Sea in the monsoon trough coincided with Lois' in the Philippine Sea, as deep low-level southwesterly flow surged eastward across the Philippine Islands. Due to strong vertical shear aloft, the tropical cyclone was slow to intensify, and finally reached a peak intensity of 50 kt (26 m/sec) on 17 August. Mark spent its short lifetime embedded in the monsoon trough and then dissipated over land. The tropical cyclone's passage along the South China coast resulted in at least one death, localized flooding and disruption of transportation.



## TROPICAL STORM NINA (14W)

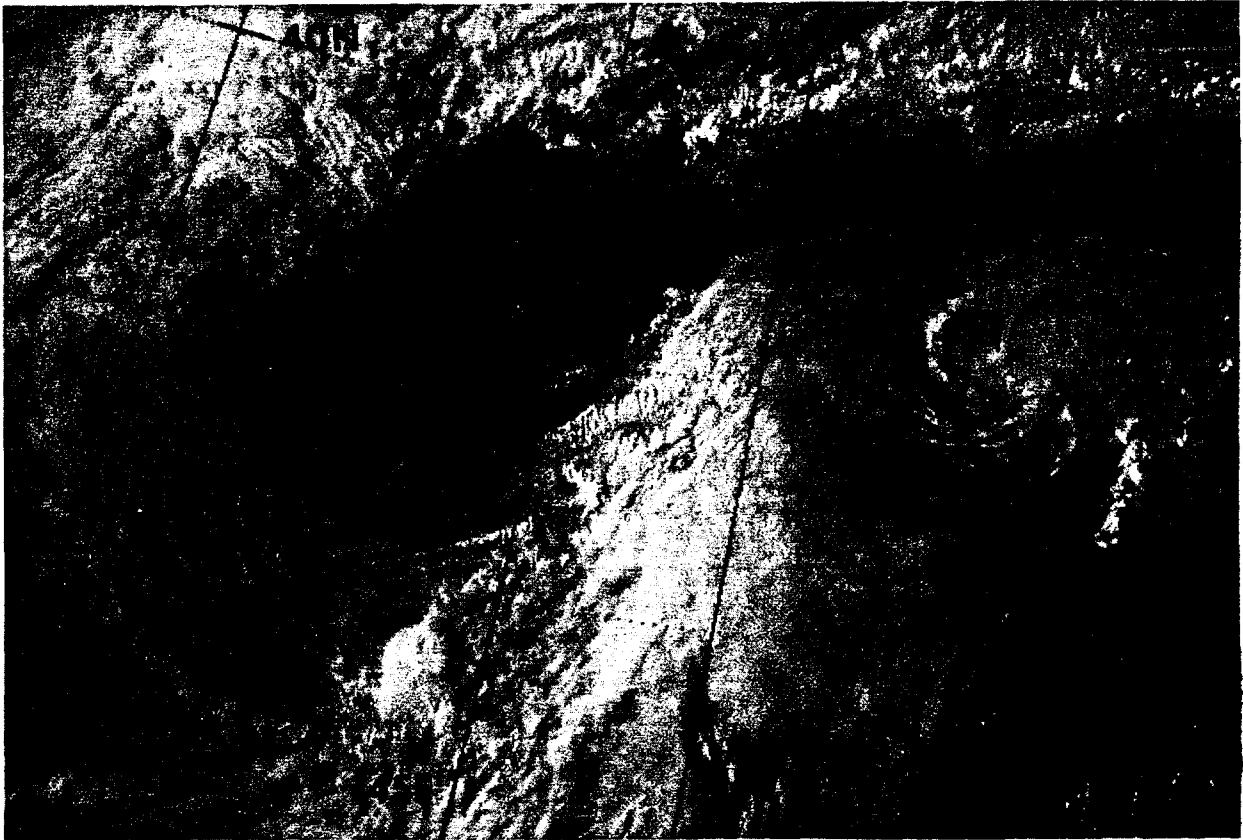


Figure 3-14-1. Tropical Storm Nina at peak intensity is separated from Lois (12W) by a broad band of monsoon cloudiness (200658Z August DMSP visual imagery).

Nina was part of a four storm outbreak in August with Kent (11W), Lois (12W) and Mark (13W). Forming as a TUTT-induced tropical cyclone under the divergent outflow from Kent (11W), Nina intensified to a peak intensity of 45 kt (23 m/sec) despite the strong vertical wind-sheared environment. Later, and most probably due to the persistence of relatively low pressure near its center, Nina became the extreme eastern end of the monsoon trough that extended east-northeastward from the South China Sea. Due to this tropical cyclone's sharp recurvature and unseasonably rapid acceleration, track errors for the three 72-hour forecasts were quite high, ranging from 450 to 880 nm (835 to 1630 km). Lois remained over open ocean for its entire life, threatening only mariners.



## TROPICAL STORM NINA (14W)

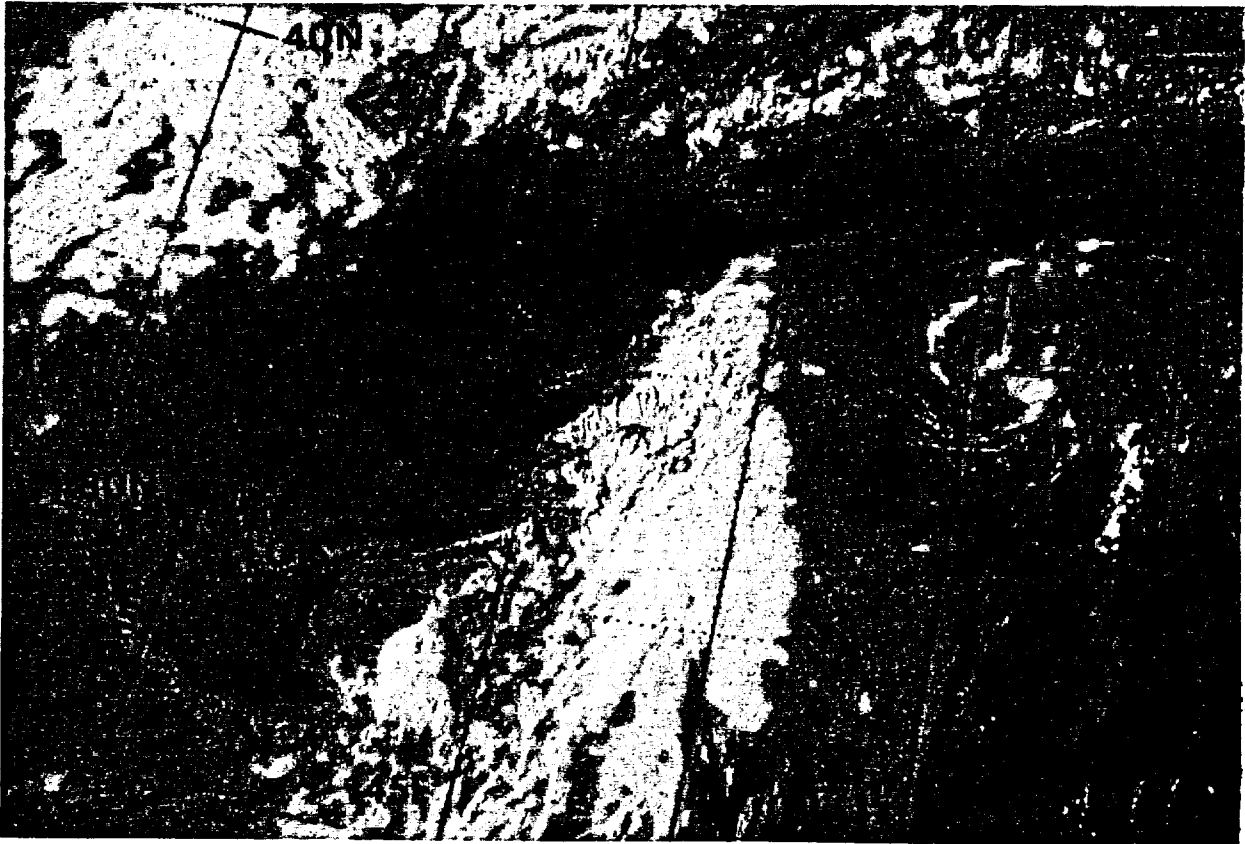


Figure 3-14-1. Tropical Storm Nina at peak intensity is separated from Lois (12W) by a broad band of monsoon cloudiness (200658Z August DMSP visual imagery).

Nina was part of a four storm outbreak in August with Kent (11W), Lois (12W) and Mark (13W). Forming as a TUTT-induced tropical cyclone under the divergent outflow from Kent (11W), Nina intensified to a peak intensity of 45 kt (23 m/sec) despite the strong vertical wind-sheared environment. Later, and most probably due to the persistence of relatively low pressure near its center, Nina became the extreme eastern end of the monsoon trough that extended east-northeastward from the South China Sea. Due to this tropical cyclone's sharp recurvature and unseasonably rapid acceleration, track errors for the three 72-hour forecasts were quite high, ranging from 450 to 880 nm (835 to 1630 km). Lois remained over open ocean for its entire life, threatening only mariners.

E 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180  
N 45

# **SUPER TYPHOON OMAR**

BEST TRACK TC-15W  
20 AUG - 06 SEP 92  
MAX SFC WIND 130KT  
MINIMUM SLP 910MB

## **LEGEND**

- 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

40

35

30

25

20

15

10

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EQ

79

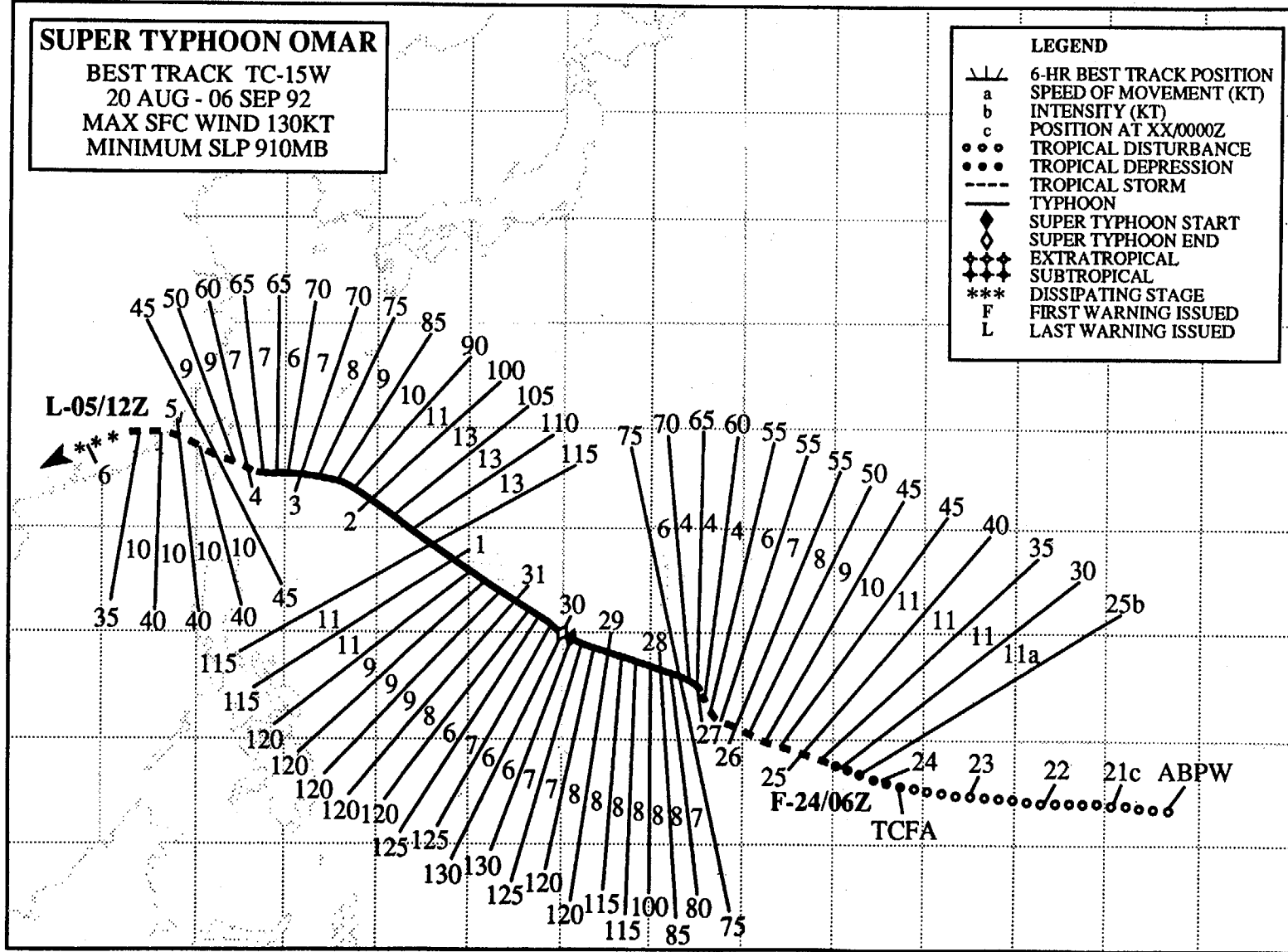
L-05/12Z

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F-24/06Z

TCFA

ABPW



## **SUPER TYPHOON OMAR (15W)**

### **I. HIGHLIGHTS**

The second super typhoon of 1992, Omar became the seventh of the eight tropical cyclones to develop in August. The tropical disturbance that became Omar was first noted over the southern Marshall Islands, at a time when Mark (13W) was weakening along the south coast of China, Kent (11W) had dissipated in the Sea of Japan, and Lois (12W) and Nina (14W) were east of Japan. Later, after moving steadily west-northwestward and intensifying, Omar wreaked havoc on Guam as it rapidly intensified immediately prior to passing directly over the island with 105 kt (54 m/sec) sustained winds. After traversing Guam, Omar continued onward into the Philippine Sea where it briefly attained super typhoon intensity. Omar then steadily weakened, passing over Taiwan as a tropical storm, and dissipated over southeastern China.

### **II. TRACK AND INTENSITY**

Based on persistent convection, the tropical disturbance that was to become Omar was first mentioned in the 200600Z August Significant Tropical Weather Advisory. During the next three days, which included the dissipation of Kent (11W) and Mark (13W), and the approaching of the extratropical transitions of Lois (12W) and Nina (14W), the monsoon trough began to reestablish itself in a more normal location, extending across the northern Philippine Islands, east-southeastward into the Caroline Islands. While this major synoptic pattern readjustment was taking place, the tropical disturbance had developed sufficiently to warrant the issuing of a Tropical Cyclone Formation Alert at 232100Z. Intensification continued, and JTWC issued the first warning at 240600Z. Coincident with Omar becoming a tropical depression 750 nm (1390 km) east-southeast of Guam and the southwesterly low-level flow deepening across the western Caroline Islands, Polly (16W) began to develop 200 nm (370 km) to the west of Guam. After Omar was upgraded to a tropical storm on the warning at 250000Z, the rate of intensification decreased due to upper tropospheric wind shear from the extensive outflow of Polly (16W), which was also intensifying. At about the same time, Omar (Figure 3-15-1) began to slow in forward speed. This slowing of development and forward motion continued until early on 27 August when Tropical Storm Omar stalled.

If the strong vertical wind shear created by Polly's proximity continued, or increased, there was a possibility that Omar's upper and lower circulation centers could decouple and further weaken the tropical cyclone. However, the circulation held together, drifted northwestward, and began to intensify. Omar (Figure 3-15-2) was upgraded to typhoon intensity at 270600Z, and 12 hours later at about 271800Z began a period of rapid intensification which lasted for the next 12 to 18 hours. By the evening of 27 August, Omar began to accelerate towards Guam. Gale force sustained winds, began to buffet Guam at 272300Z about the time that a visible eye appeared on satellite imagery. This was followed by the onset of destructive winds, in excess of 50 kt (26 m/sec), which commenced at 280300Z and lasted for 16 hours. These sustained winds rose steadily until they peaked at 105 kt (54 m/sec) with gusts to 130 kt (67 m/sec) in the western half of the eye wall (Figure 3-15-3). As the eye passed across the island, the eastern half of the eye wall followed, battering Guam with torrential rain again and strong winds from the opposite direction (Figure 3-15-4). While Omar's eye passage coincided with one of the highest astronomical tides of August (Figure 3-15-5), the storm surge was not as high as expected. Apparently the rapidly changing wind direction that occurred with eye passage limited the fetch and kept the inundation to a lower level than anticipated. Some low-lying areas on Guam suffered total

wave runup as high as 10 feet on the north shore (Figure 3-15-6). In addition, the typhoon dropped over a foot of rain on the northern half of the island with a maximum of 18 inches (460 mm) measured at the National Weather Service Observatory at Taguac (WMO 91217).

After mauling Guam, Omar continued to intensify as it moved across the Philippine Sea, and, at 291800Z, briefly attained super typhoon intensity (Figure 3-15-7). Then a gradual weakening trend set in. On 4 September, Omar passed across Taiwan as a tropical storm and, on 5 September, it moved into southeastern China and dissipated.

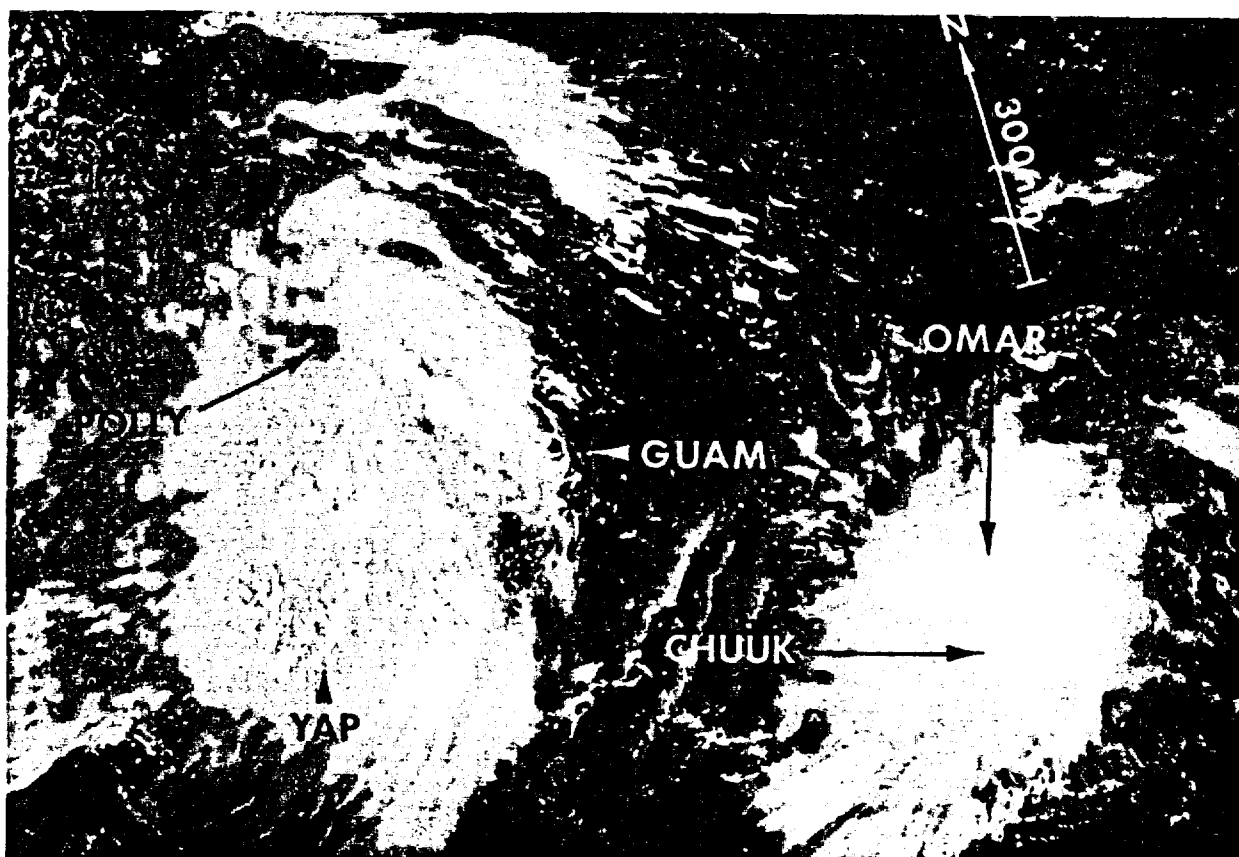


Figure 3-15-1. Omar Passes north of Chuuk as Polly (14W) consolidates to the west of Guam (242320Z August DMSP visual imagery).

### III: FORECAST PERFORMANCE

Overall mean errors for the JTWC track forecasts were 75, 160, and 270 nm (135, 300, and 500 km) for 24, 48 and 72 hours, respectively. This was 20% better than the climatology-persistence (CLIPER) baseline for skill at all forecast time intervals. With regard to intensity, the JTWC 24-hour forecasts were representative of events, except for a brief period when they were consistently 20 to 40 kt (37 to 74 m/sec) low for a day and a half before Omar struck Guam.

#### IV. IMPACT

Typhoon Omar was the most damaging typhoon to strike Guam since Typhoon Pamela in 1976. On Guam, Omar caused an estimated \$457 million of damage, destroyed or severely damaged over 2158 homes leaving nearly 3000 people homeless in temporary shelters until a 200-tent "city" could be erected. Omar almost completely disabled the island-wide power distribution system which in turn caused the water pumping system to fail. Long term mitigation measures such as the erection of concrete power poles limited their damage. Over 400 wooden poles and 20 to 30 concrete poles were destroyed and the damage was limited to approximately \$16 million. Because they could not sortie, two of the Navy's fast supply ships, USS Niagara Falls and USS White Plains, went aground in Apra Harbor after they broke their moorings. Finally, Omar interrupted communications, and ground and air transportation. Although 200 individuals received emergency treatment for typhoon-related injuries, there were no typhoon-inflicted deaths. The efforts of a joint task force, formed to coordinate the civilian and military relief efforts, in addition to airlift and volunteer efforts, both organized and grassroots, were instrumental in getting the debris cleaned up and the island community back on its feet in only a few weeks.

Omar's passage across Taiwan resulted in two deaths, at least 12 people were injured, a major interruption of electrical power, and flooding. Later, as the tropical cyclone dissipated over southeastern China, torrential rains led to localized flooding as far west as the Hong Kong New Territories.

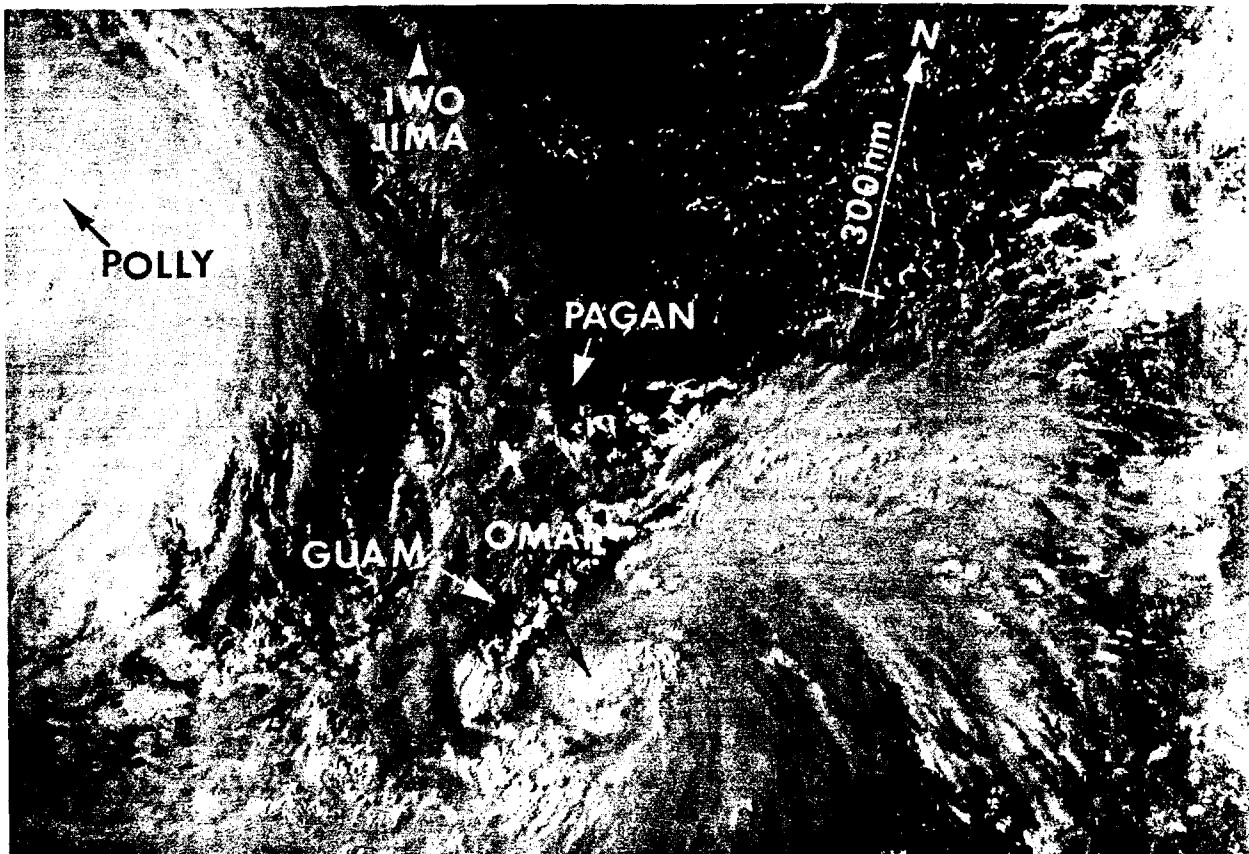


Figure 3-15-2. Omar's convection begins to coil tightly as the typhoon starts to accelerate toward Guam. The outflow across Omar from Polly (16W) to the northwest is starting to weaken (270709Z August DMSP visual imagery).

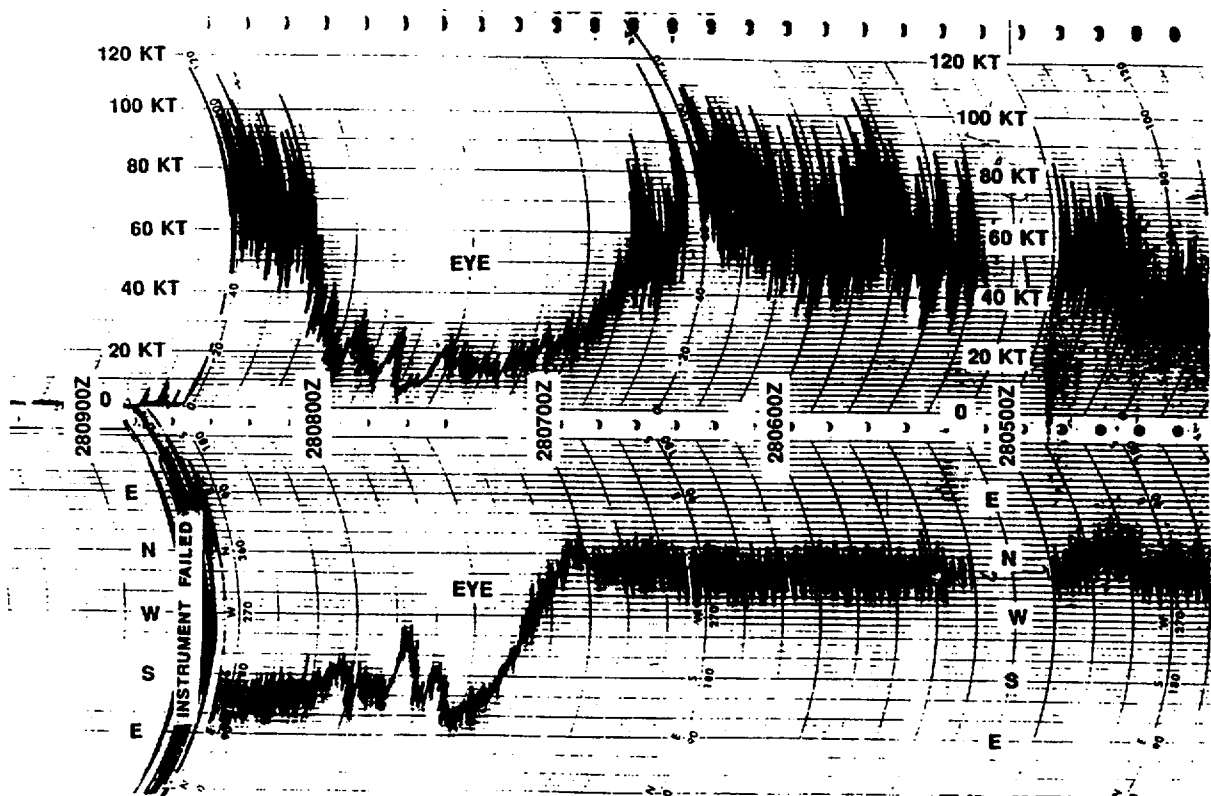


Figure 3-15-3. Wind speed and direction record of Typhoon Omar's passage over NOCD, Agana, Guam on 28 August. Note the wind instrument failed shortly after it entered the eye wall for a second time.

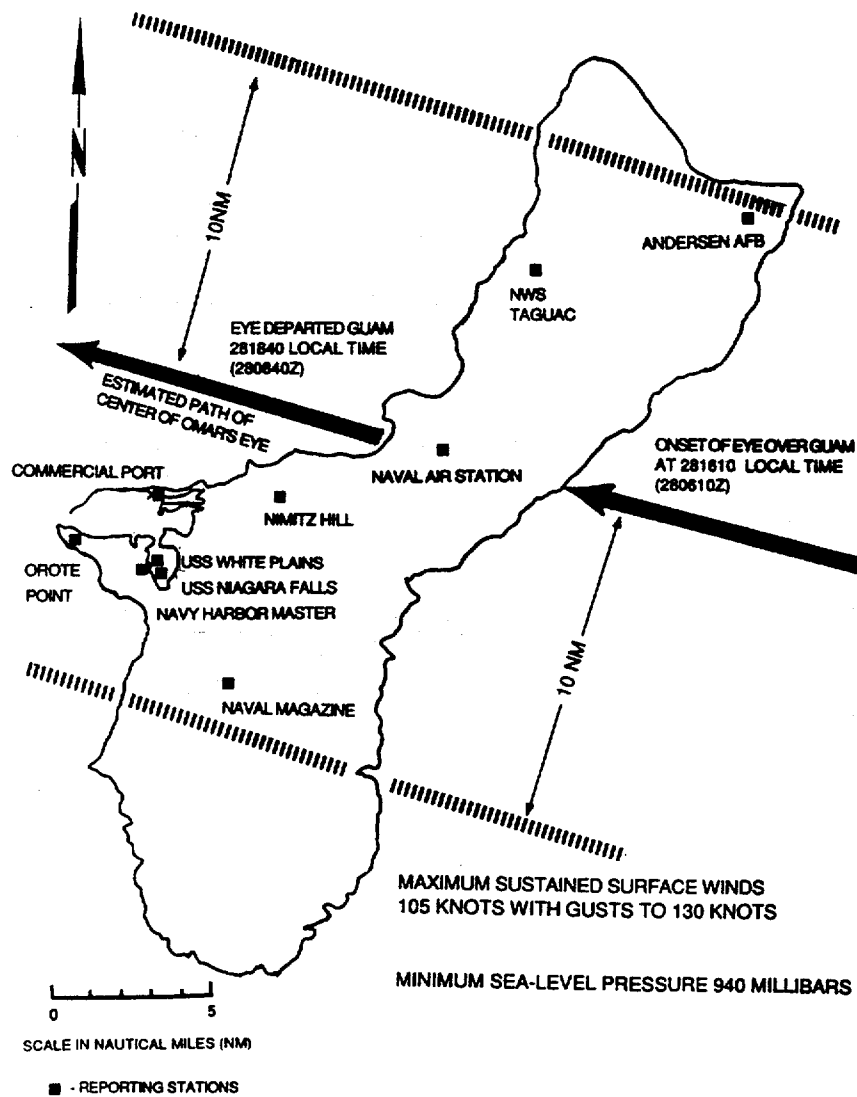


Figure 3-15-4. The geometric center of Omar's 20 nm (37 km) diameter eye with a minimum sea-level pressure of 940 mb tracked across the center of Guam on 28 August.

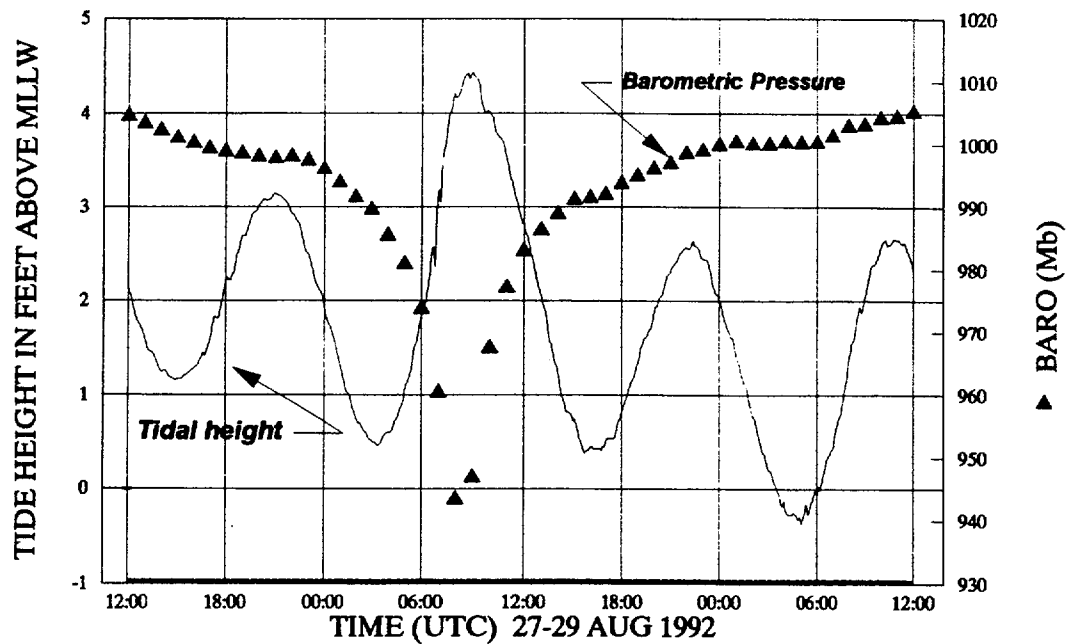


Figure 3-15-5. The NOAA-National Ocean Service (NOS) tide station record of Typhoon Omar's passage over Apra Harbor on the western side of Guam. The eye passage coincided with one of the highest astronomical tides of August (Record courtesy of NOAA/NOS Pacific Operations Section).



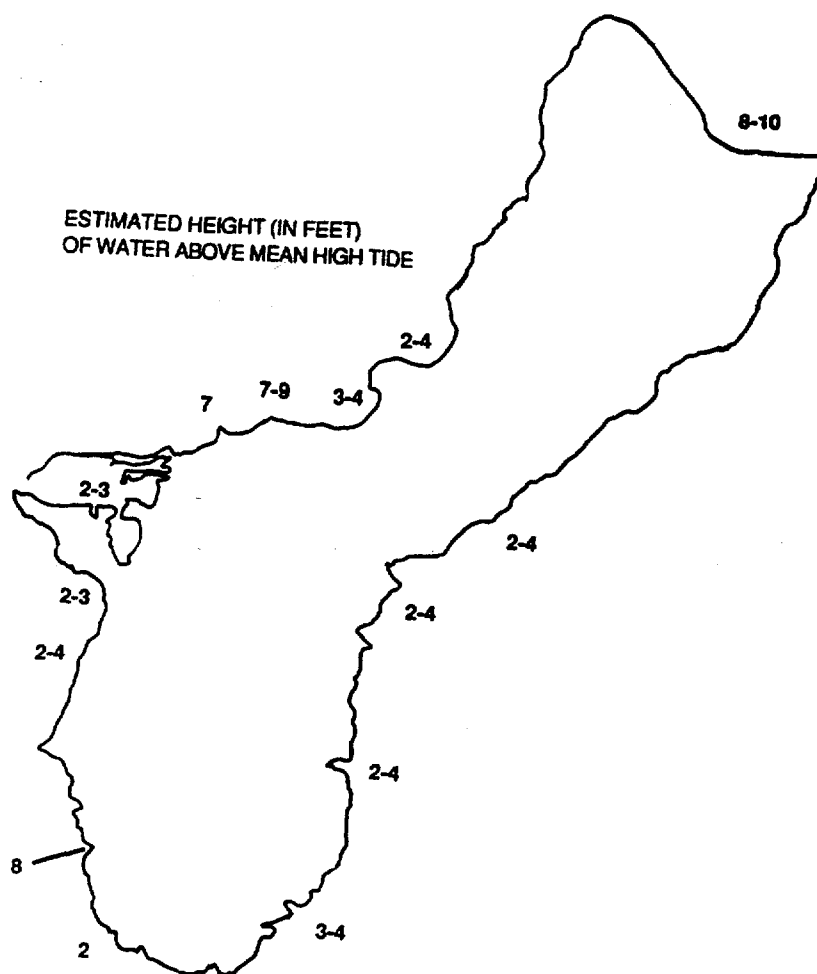


Figure 3-15-6. Maximum "storm surge" heights (which include astronomical tide, hydrostatic effects, and winds driven wave effects) at selected locations on Guam as estimated following Omar's passage.

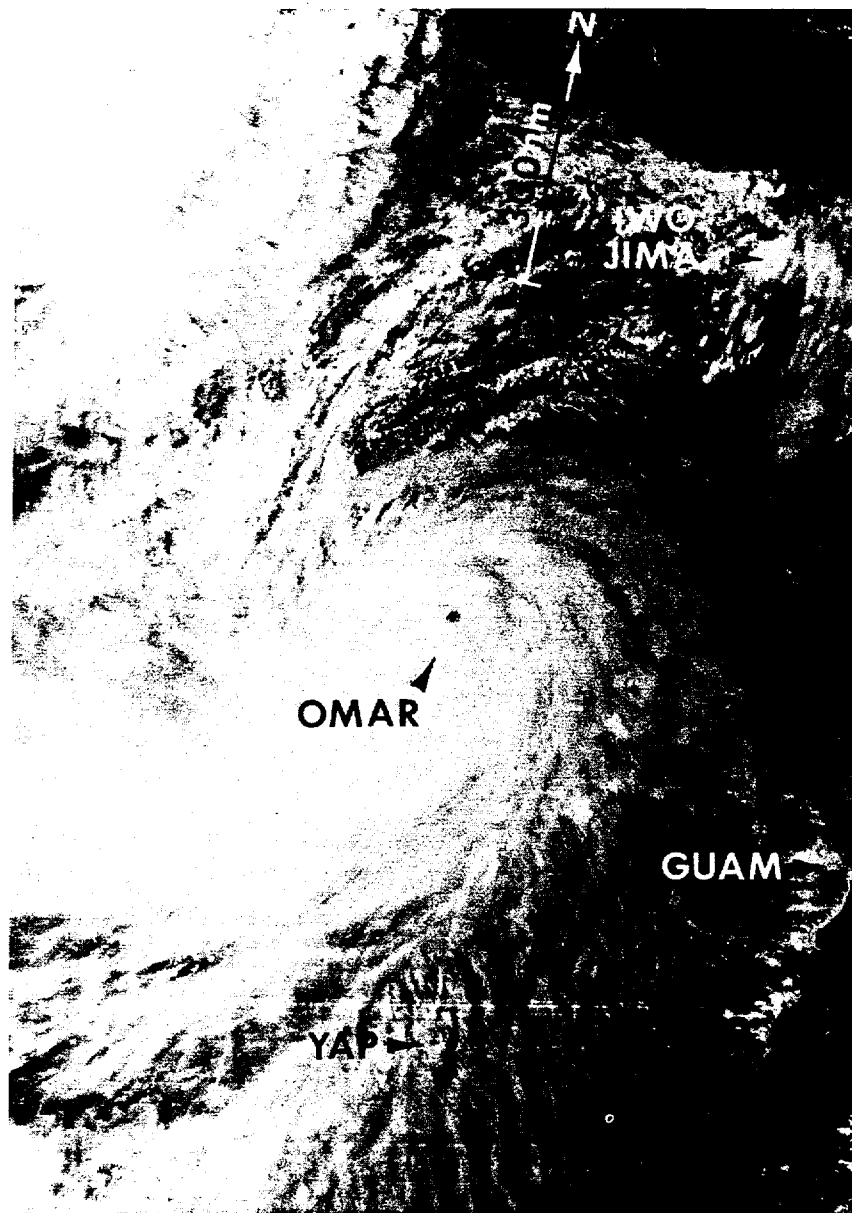


Figure 3-15-7. Omar with an 18 nm (33 km) diameter eye is still packing maximum sustained surface winds of 120 kt (62 m/sec) winds two day after peaking at 130 kt (67 m/sec) (310535Z August NOAA visual imagery).

E 115 120 125 130 135 140 145 150 E

N 40

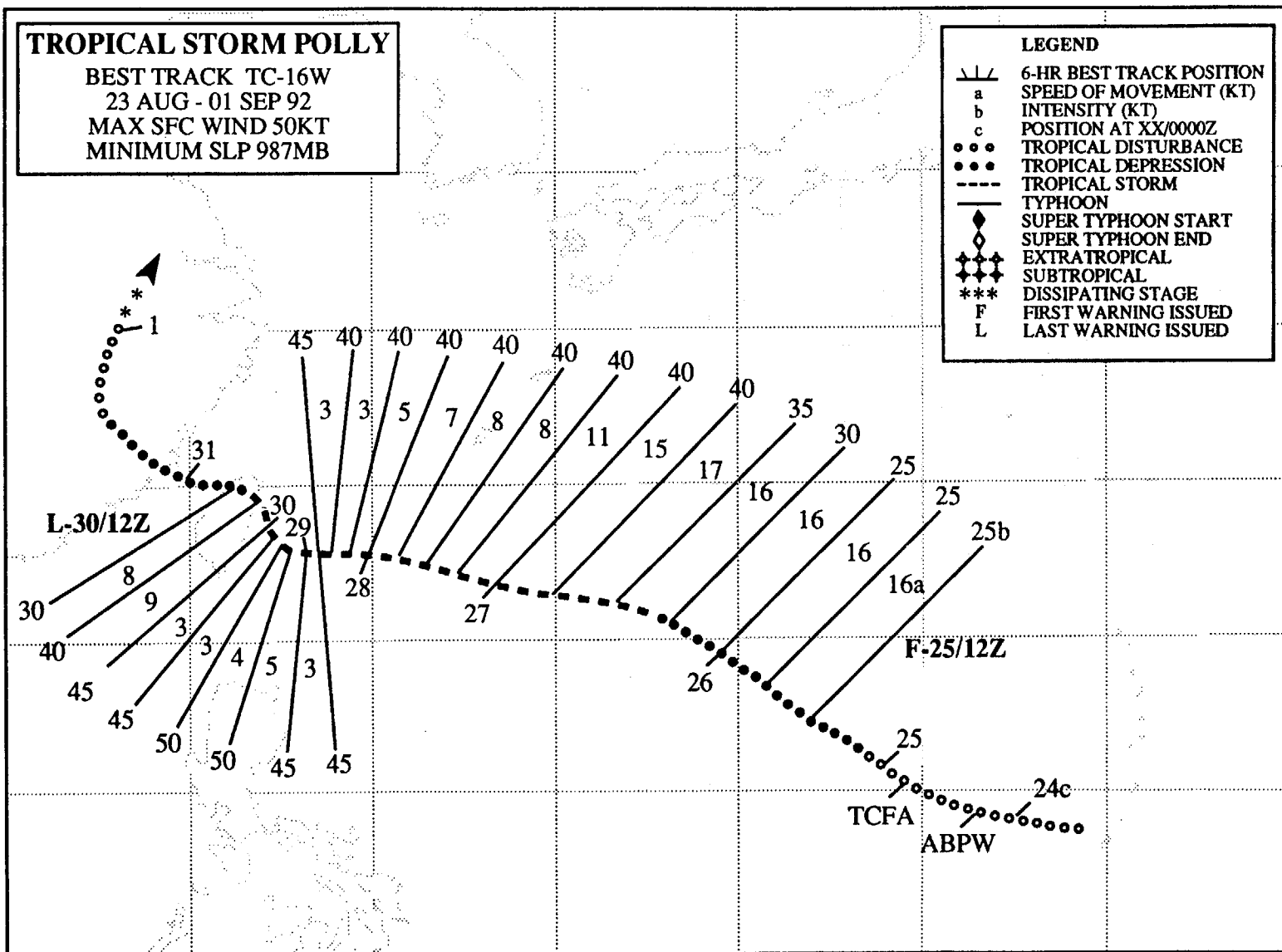
**TROPICAL STORM POLLY**  
 BEST TRACK TC-16W  
 23 AUG - 01 SEP 92  
 MAX SFC WIND 50KT  
 MINIMUM SLP 987MB

**LEGEND**

- 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

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N 10



## **TROPICAL STORM POLLY (16W)**

### **I. HIGHLIGHTS**

The eighth and final significant tropical cyclone of August, Polly developed along with Omar (15W) as part of a major relocation of the monsoonal trough. Polly was unusual in that throughout most of its life, it maintained the pattern of a monsoon depression with a ring of peripheral gales and a broad band of deep convection around a large, relatively cloud free, central area of light-and-variable winds. The outflow aloft from this tropical storm appeared to play an important role in delaying the intensification of Typhoon Omar (15W), when the typhoon was approaching Guam. Although Polly never reached typhoon intensity, it did have quite an impact on eastern Asia.

### **II. TRACK AND INTENSITY**

On 24 August, as the low-level southwesterly flow built westward across the Philippine Sea reestablishing the monsoon trough, the disturbance that developed into Polly appeared as an area of persistent convection just west of Guam. The tropical disturbance was first discussed on the 240600Z Significant Tropical Weather Advisory. A cell in the tropical upper-tropospheric trough (TUTT) dug in west of the disturbance, enhancing the outflow and convective organization through the night. This caused JTWC to issue a Tropical Cyclone Formation Alert at 241900Z. The disturbance continued to increase in organization and began to separate from the general monsoon cloudiness. At 251200Z, JTWC issued the first warning on Tropical Depression 16W. The depression slowly intensified, and was upgraded to a tropical storm at 270000Z. Post analysis indicates that Polly was probably became a tropical storm about 12 hours earlier, at 261200Z.

From 25 to 27 August, the tropical storm moved to the west-northwest at an average speed of 16 kt (30 km/hr). From 27 to 29 August, Polly gradually slowed from 15 to 3 kt (28 to 6 km/hr) of motion, as it approached Taiwan, and became the anchor-low of the major western North Pacific monsoon gyre which was northeast-southwest oriented across the South China Sea. At 290600Z, Polly reached its peak intensity of 50 kt (26 m/sec). During the next 24 hours, it drifted slowly to the northwest, then made landfall on northeastern Taiwan at 300600Z (Figure 3-16-1). The tropical storm weakened to a depression over mountainous Taiwan and accelerated into southeastern China on 31 August where strong upper-level winds from the east Asian upper-level tropical easterly jet sheared the central convection from Polly's center and the tropical cyclone dissipated on 1 September.

During its life, Polly never developed a core of persistent central convection. With a large, poorly defined eye, Polly took on the characteristics of a monsoon depression with a band of strong low-level winds displaced to the east and north some 150-400 nm (280-740 km) from the center and relatively weak winds to the west and southwest (Figure 3-16-2).

From late 26 to late 27 August, Polly's upper-level outflow increased dramatically to the northeast and imposed strong upper-level shear on Typhoon Omar (15W) to the east. The increased subsidence between the two storms build a mid-level ridge between them which temporarily blocked the westward motion of Omar. The shear also slowed Omar's intensification. However, once the distance between the two storms increased and the shear abruptly decreased on the morning of 28 August Omar began to rapidly intensify. Thus, Polly greatly affected the behavior of Omar.

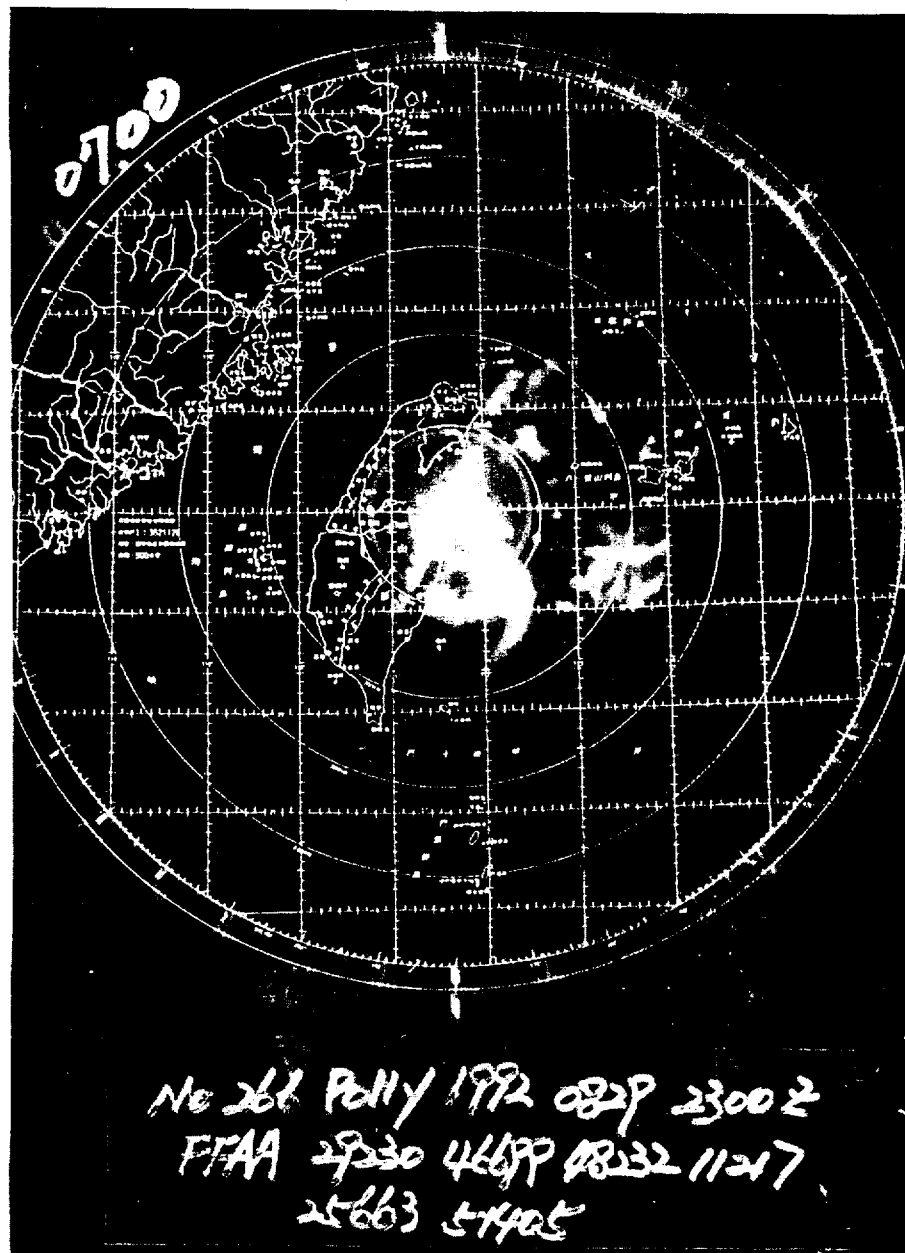


Figure 3-16-1. Although Polly is weakening, its eye remain's visible on the radar at Hualein (WMO 46699) (292300Z August radar photo courtesy of the Central weather Bureau, Taipei, Taiwan).

### III. FORECAST PERFORMANCE

Overall JTWC mean track forecast errors were worse than normal at 12 to 24 hours, but better at 48 and 72 hours. This was primarily the result of relatively large along-track or speed errors for the short range forecasts, but relatively low cross-track or pointing errors for all of the forecasts. Forecasters did not expect the anchor-low of the monsoon trough to immediately accelerate to the west-northwest in the early stages. They did not anticipate the slow down that began on 28 August. As Polly moved westward, forecasters slowed the tropical cyclone's motion to more climatological speeds. This allowed the longer range forecasts to benefit from Polly's slow speed near Taiwan.

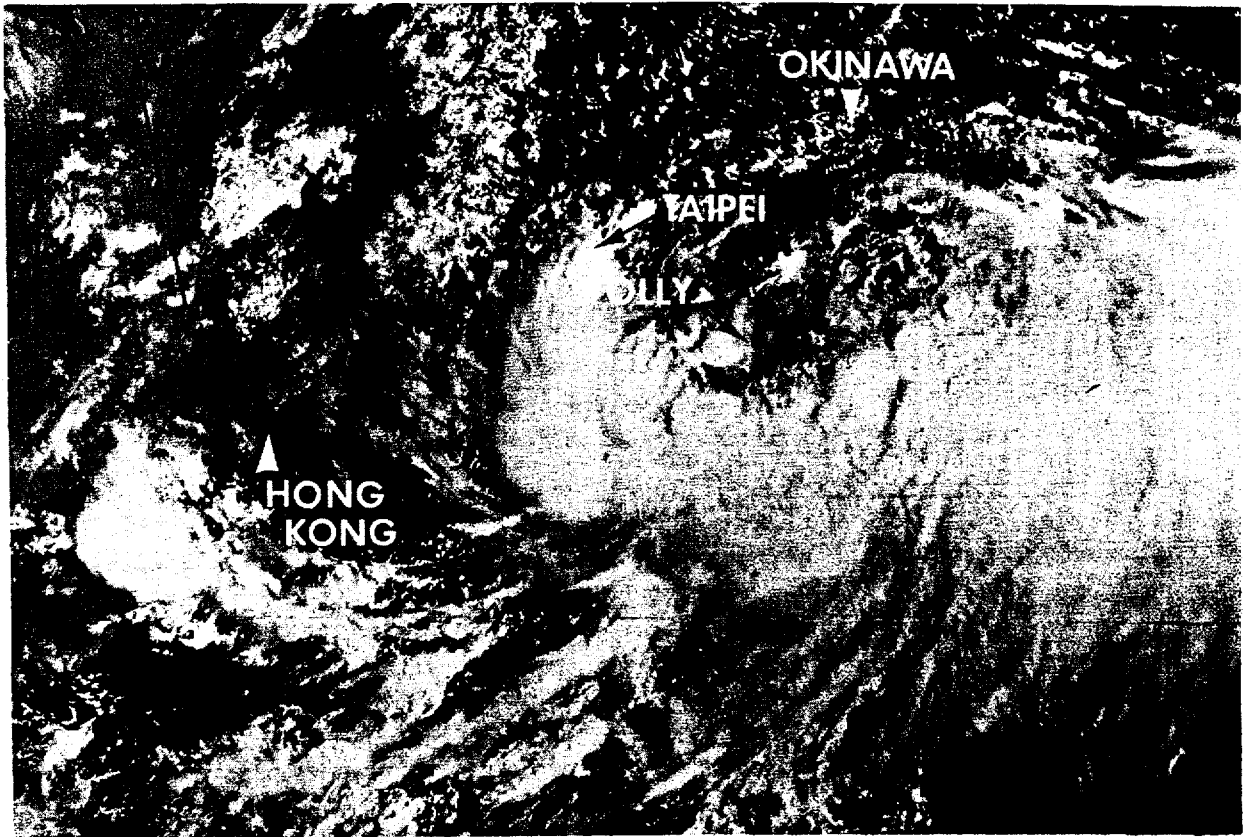


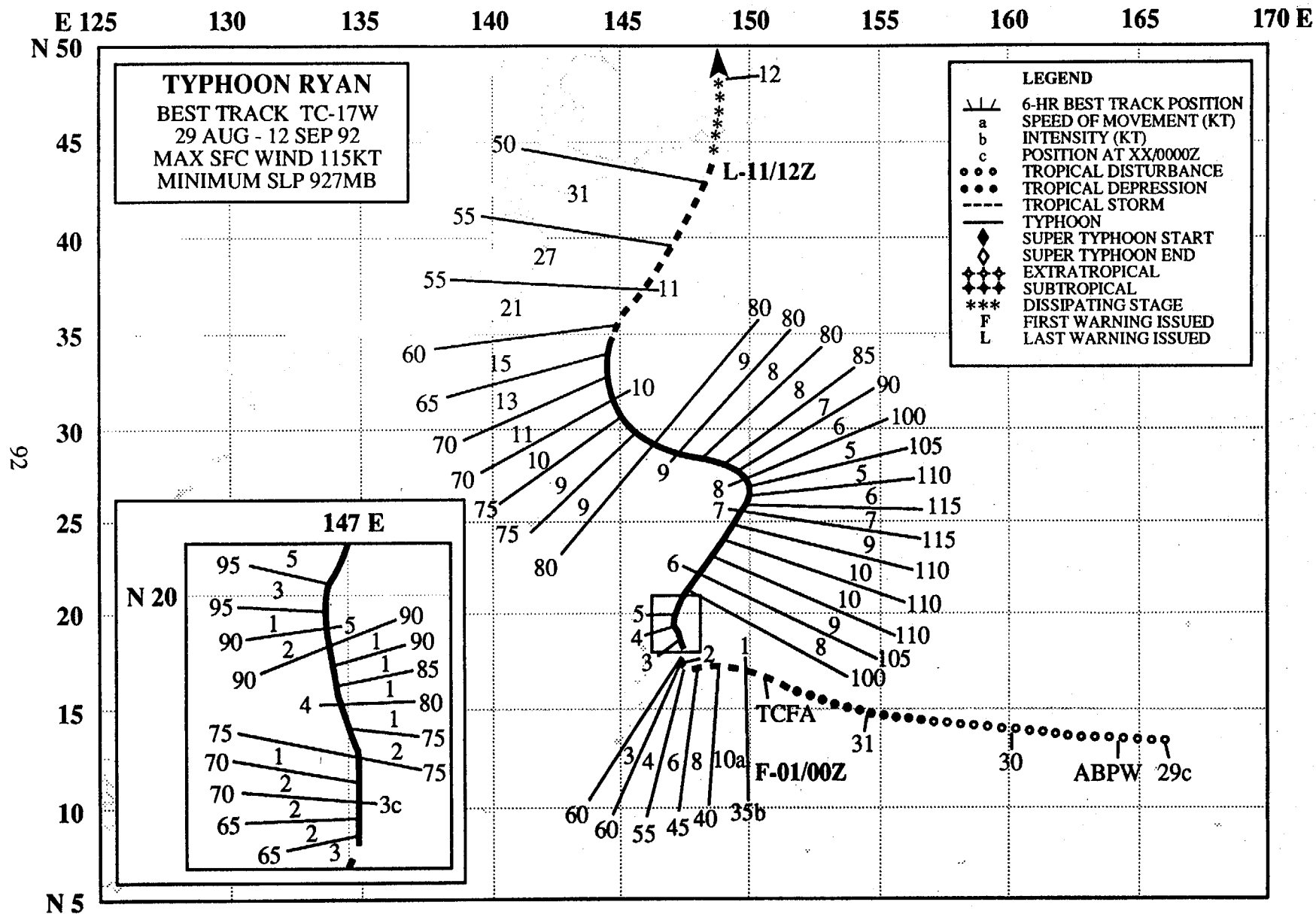
Figure 3-16-2. Polly's large, relatively cloud free, circulation center is supported by a deep band of convection to the south (280107Z August DMSP visual imagery).

JTWC accurately anticipated slow development and only development to minimum typhoon intensity. As a result, average intensity forecast errors for the first 48 hours were 10 kt (5 m/sec) or less. Seventy-two hour forecast errors were 19 kt (10 m/sec), primarily as a result of early forecasts anticipating peaking in three days instead of the observed five days.

In general, the dynamic models performed poorly on Polly. However, the FNOC Beta Advection Model (FBAM) in the mean out performed all of the forecast guidance. This model seems to do well with the motion of cyclones associated with large monsoon gyres. JTWC forecasts were superior to CLIPER at 24 hours, but nearly identical at 48 and 72 hours.

#### IV. IMPACT

Polly's greatest impact to forecasters was its effect on Typhoon Omar's (15W) motion and intensity. Polly created more than three days of gale- or near gale-force winds over Okinawa and the north Ryukyu Islands. The strong cross winds hampered flying operations on Okinawa, even though Polly never got closer than 300 nm (555 km). In northern Luzon, the torrential rains, associated with Polly's passage to the north, caused lahars, or steaming mudflows, on the slopes of Mount Pinatubo that claimed five lives. On Taiwan, Polly's rain and wind were responsible for at least eight fatalities, widespread flooding that inundated thousands of homes and acres of farmland, and electrical power outages. As the remnants of the tropical storm slammed into southeastern China, heavy rains and flooding led to at least 165 deaths, the loss of 11,000 homes, 1400 fishing boats, and thousands of livestock.



## **TYPHOON RYAN (17W)**

### **I. HIGHLIGHTS**

The first of five significant tropical cyclones to form in September, Ryan became part of a three storm outbreak east of 150° E longitude along with Typhoons Omar (15W) and Sibyl (18W). Although Ryan initially took a west-northwestward course similar to the two preceding tropical cyclones, it later stalled, and then changed to a north-orientated track. Two days after transitioning to an extratropical low east of Hokkaido, the remnants of Ryan could still be identified, as an occluded low continuing northward over Siberia, north of the Sea of Okhotsk.

### **II. TRACK and INTENSITY**

On 29 August, one day after Typhoon Omar (15W) roared across Guam knocking the Joint Typhoon Warning Center out of commission, the Alternate JTWC (AJTWC) noticed a persistent area of convection east of the Mariana Islands and included it on the 290600Z Significant Tropical Weather Advisory. As this persistent area of convection at the extreme eastern end of the monsoon trough moved west-northwestward, the tropical disturbance steadily increased in convective organization, prompting AJTWC to issue a Tropical Cyclone Formation Alert at 312100Z, and the first warning shortly afterward at 010000Z September.

Instead of continuing along the axis of the monsoon trough to the west-northwest, as Omar (15W) and Polly (16W) had done, Ryan stalled on 2 September, and abruptly changed course in response to a weakening of the subtropical ridge to the north caused by the passage of a deep mid-level trough. As the tropical cyclone drifted northward in a weak steering environment, it gradually intensified and became a typhoon at 021200Z.

On 5 September, a second mid-level trough began to deepen near Honshu and effect the subtropical ridge. As a consequence, the typhoon (Figure 3-17-1) changed to a north-northeast track, and reached a peak intensity of 115 kt (59 m/sec) at 070000Z. When the ridge reestablished itself after the trough's passage on 8 September, the typhoon began to move northwestward. Then, on 10 September, the cyclone turned east of north again, and began to accelerate ahead of a third mid-latitude trough. At 111200Z, Ryan transitioned into an extratropical low east of Hokkaido and JTWC, which had resumed primary warning responsibility on 8 September, released a final warning. The extratropical remnants of Ryan continued northward across the Sea of Okhotsk and was still evident as a large occluded low over Siberia two days later.

### **III. FORECAST PERFORMANCE**

Ryan's first 28 warnings were issued by AJTWC and the last 15 by JTWC. Early track forecasts predicted that Ryan would be a straight-runner to the west, however, after it became apparent that the track would become north-oriented, the errors were noticeably reduced. Overall mean JTWC track forecast errors were 97, 238 and 360 nm (180, 445, and 665 km) for 24, 48 and 72 hours, respectively. Although the mean errors at 48 and 72 hours were larger than average, JTWC and AJTWC did show skill by bettering CLIPER by 70% on this harder-than-average typhoon. However, for 72-hour forecasts, the best overall guidance was provided by OTCM, which in the mean, was considerably better than JTWC/AJTWC by 139 nm (255 km). With regard to intensity, the short range forecasts verified well. Nevertheless, for the 36-hour period beginning at 021800Z, the 72-hour intensity forecasts were low by 20 to 50 kt (10 to 26 m/sec) due to anticipated weakening that did not occur.



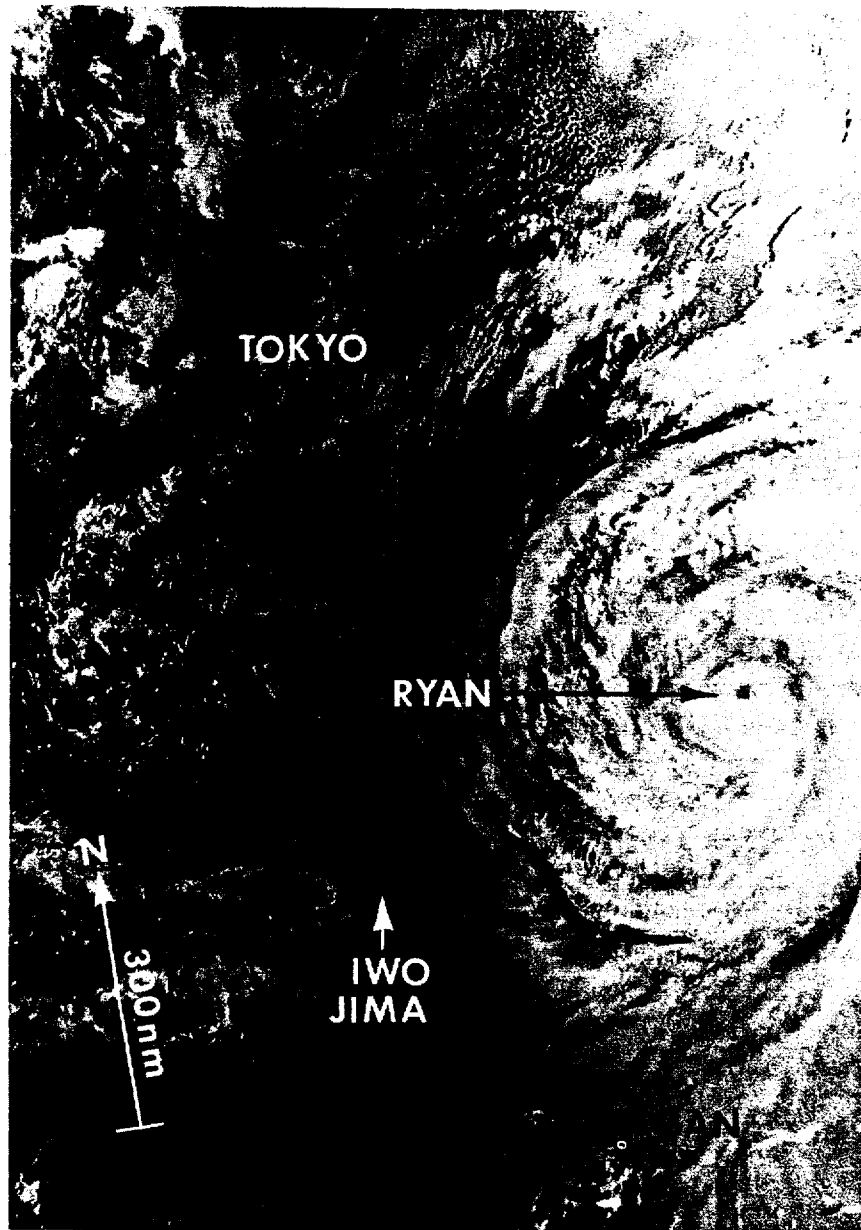
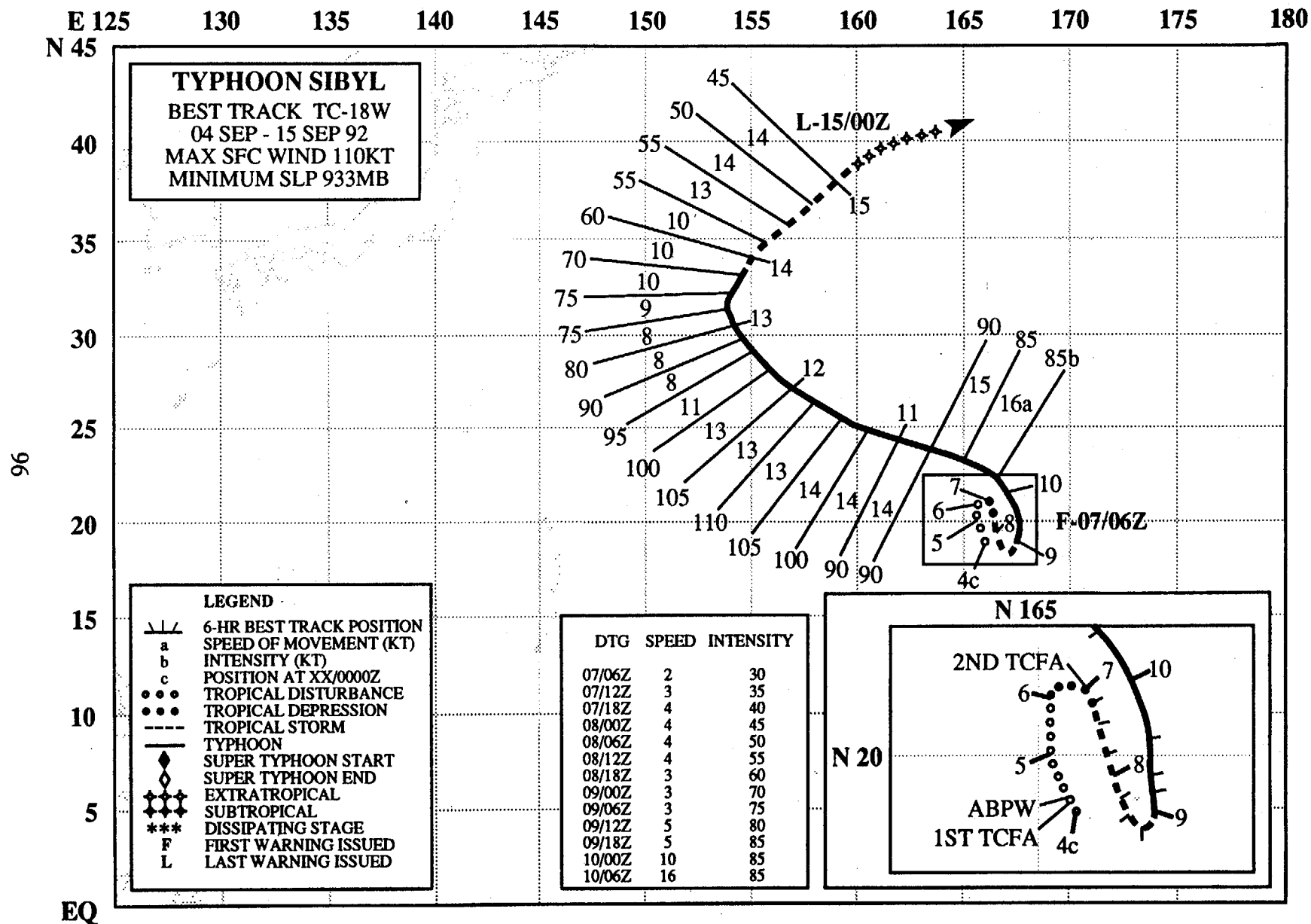


Figure 3-17-1. Just after reaching its peak intensity, Typhoon Ryan is located southeast of Tokyo (072238Z September NOAA visual imagery).

#### IV. IMPACT

Typhoon Ryan remained over open ocean and no reports of property damage or loss of life were received. While Ryan was developing northeast of Saipan, and moving erratically, it threatened the sparsely populated islands of Pagan and Agrihan which were in Condition of Readiness One for nearly two days. The system also enhanced the southwest monsoon between Guam and Saipan, delaying the arrival of barges carrying bucket trucks and line crews from Saipan to help restore power on Guam.

This was the first time in recent history that the AJTWC had to activate in the middle of the western North Pacific tropical cyclone season for JTWC and keep the Pacific Command's warning system running for a long period, 11 days. AJTWC rose to the challenge and the excellent statistics bear this out.



## TYPHOON SIBYL (18W)

### I. HIGHLIGHTS

The second of five significant tropical cyclones to form in September, Sibyl, like Ryan (17W), formed at the extreme eastern end of the monsoon trough. But unlike Ryan, Sibyl underwent a complex interaction with a cyclonic cell in the Tropical Upper-Tropospheric Trough (TUTT), and later recurved. For five days Sibyl exhibited erratic motion and slowly intensified near Wake Island, before moving to the northwest and recurving.

### II. TRACK AND INTENSITY

The tropical disturbance that became Sibyl formed at the eastern end of the monsoon trough that included both Typhoon Omar (15W) and Typhoon Ryan (17W). As Ryan (17W) intensified, the falling surface pressures along the monsoon trough extended eastward into the Wake Island area. In response, the surface pressure at Wake Island (WMO 91245) had been slowly, but steadily falling since 1 September (Figure 3-18-1). The combination of the falling surface pressures, soundings from Wake Island (WMO 91245) showing strengthening southwesterlies, and the appearance of an exposed low-level circulation center on the satellite imagery, prompted the Alternate JTWC (AJTWC) to issue a Tropical Cyclone Formation Alert (TCFA) at 040400Z.

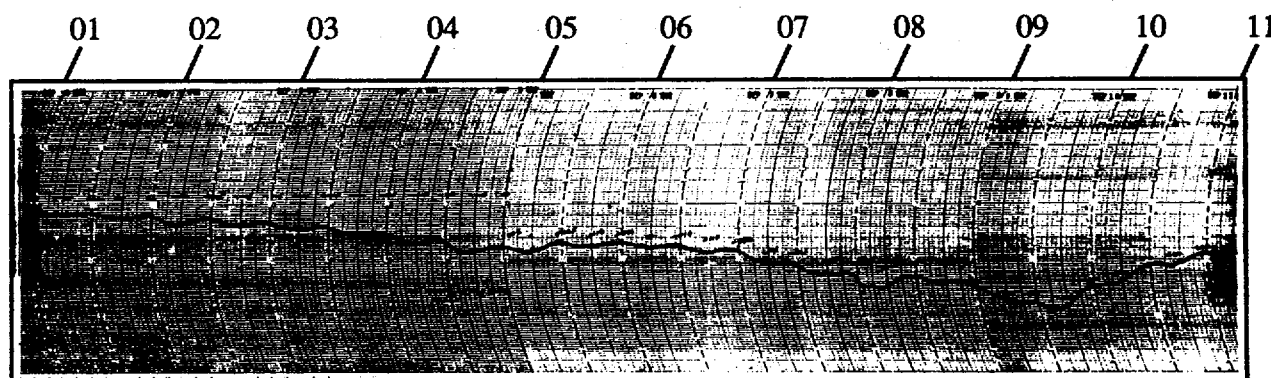


Figure 3-18-1. Barograph trace for the period 01-11 September for Wake Island (WMO 91245) showing the steadily falling pressures from 010000Z to 091445Z associated with the extension of the monsoon trough into the area, and the formation and intensification of Sibyl near the island. (Microbarograph trace courtesy of the National Weather Service Office, Wake Island).

In the TUTT over the alert area, in conjunction with the increasing outflow from Ryan (15W), a cyclonic cell developed. As the complex interaction between the tropical disturbance and the TUTT-cell progressed, the deep convection was sheared from the low-level circulation center by strong 35- to 45-kt (18- to 23-m/sec) winds around the TUTT-cell at 200 mb. As a result, the TCFA was canceled at 050400Z. Though the strong vertical wind shear remained over the area, the stronger than normal low-level winds remained. The ambient surface pressure near Wake Island continued to fall, and the tropical disturbance persisted in the form of a monsoon depression. A second TCFA, issued at 070000Z, discussed the gales, and the presence of a low-level circulation center evident in the synoptic and satellite data. The reappearance of central convection resulted in AJTWC issuing the first warning at 070600Z. Subsequently, Sibyl was upgraded to tropical storm intensity at 071800Z as the central convection expanded displacing the TUTT-cell aloft farther to the north. The tropical storm continued to intensify,

and a visible eye developed in the central dense overcast. The resulting satellite intensity estimate of 65 kt (33 m/sec) was the basis for Sibyl's upgrade to typhoon on the 090000Z warning issued by JTWC. At 091445Z, Wake Island recorded its lowest pressure, 984.5 mb, and northwest winds of 35 gusting to 48 kt (18 G 25 m/sec) at 091500Z, as Typhoon Sibyl finally began moving away.

Until 9 September, Sibyl's erratic track appeared to be the consequence the southwest flow associated with the interaction of the monsoon flow and with the easterlies of the subtropical ridge to the north and east of Wake Island. The TUTT may have played a role in the erratic movement as well. This complex synoptic pattern changed on 9 September, and Sibyl made an abrupt track change to the north. By 10 September the typhoon had accelerated and had settled into a more normal northwestward course under the influence of the subtropical ridge (Figure 3-18-2). Sibyl continued tracking toward the northwest until 13 September, when it passed through a break in the mid-tropospheric subtropical ridge and recurved. The final warning was issued by JTWC at 150000Z as Sibyl became extratropical and accelerated to the northeast.

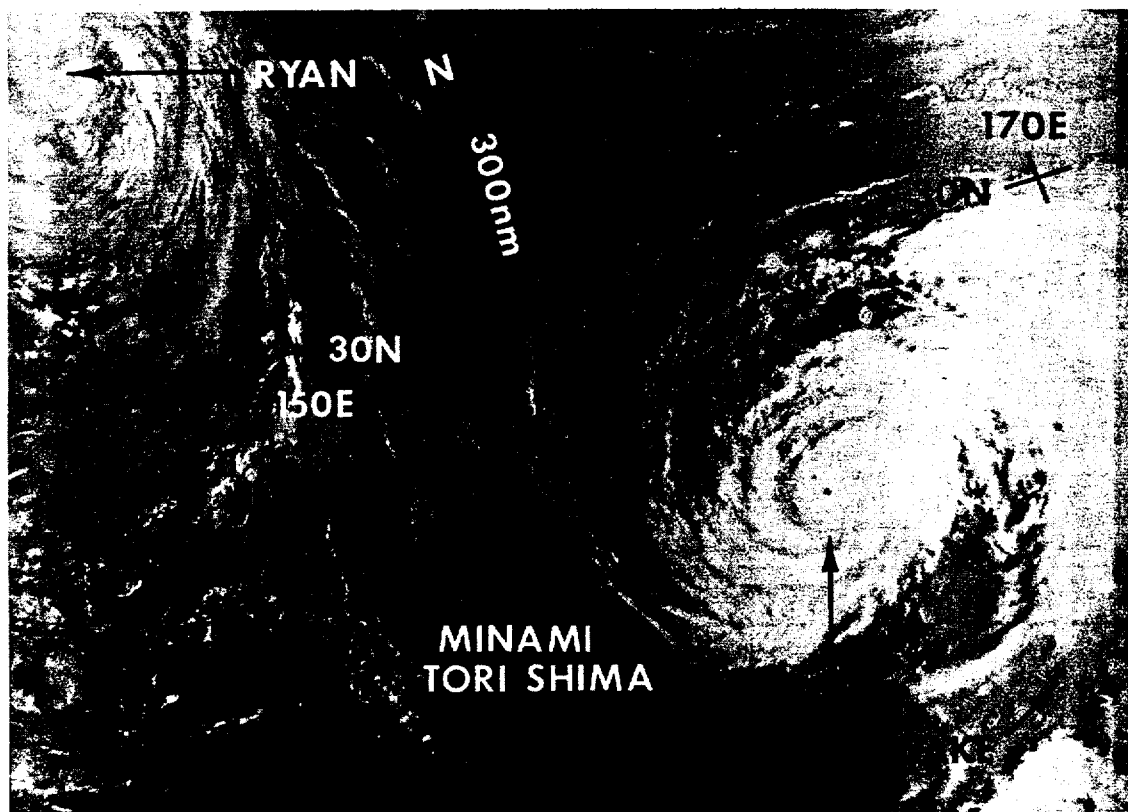


Figure 3-18-2. Typhoon Sibyl finally moves away from Wake Island. Typhoon Ryan (17W) is visible at the top left of the picture (102133Z September NOAA visual imagery).

### III. FORECAST PERFORMANCE

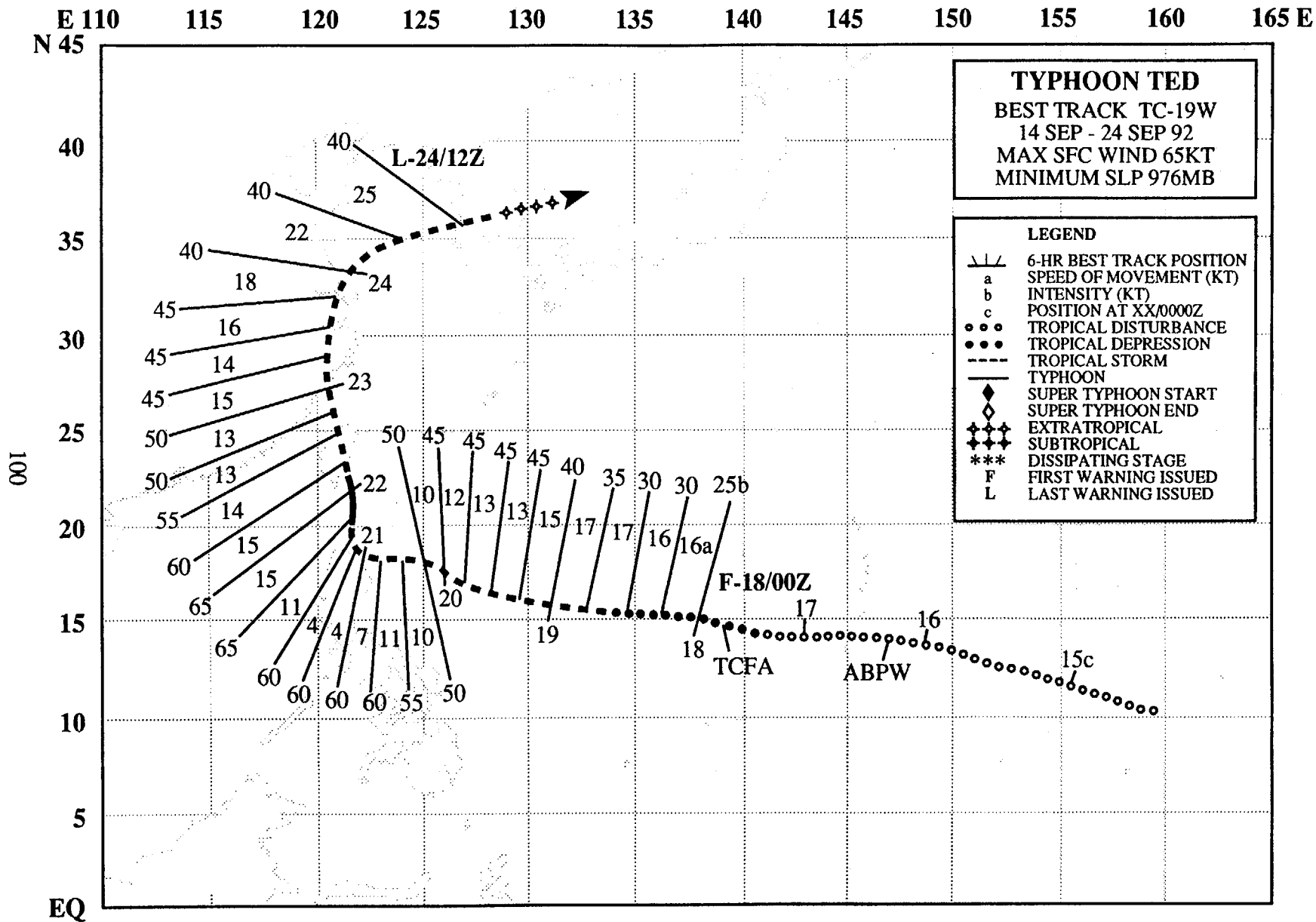
Sibyl proved to a difficult system for AJTWC/JTWC to forecast. The overall mean track errors were 100, 194 and 305 nm (185, 360 and 565 km) for the 24-, 48 and 72-hour forecasts, respectively. While these are below average, they would have been much larger had Sibyl not moved so slowly. Although AJTWC/JTWC showed skill overall on the 24-hour forecasts, CLIPER, which provides the performance baseline, was superior at the 48- and 72-hour points with 10% and 30% better performance, respectively.

With regard to intensity, the short term forecasts were good, however, the extended outlooks for 72-hours were low by 20 to 45 kt (10 to 23 m/sec) for the first day and a half, and high by 40 to 55 kt (21 to 28 m/sec) for a day after 110600Z.

### IV. IMPACT

Although Wake Island was buffeted by gales for days, no major damage or injuries were reported. Some minor water damage occurred, and Wake Island was in Condition of Readiness 1 for a day.

As with Typhoon Ryan (17W), AJTWC warned on Sibyl while JTWC was incapacitated. However, many of the direct telephone discussions with customers in Micronesia, including Wake Island, were handled by the JTWC, Guam forecasters. JTWC was able to resume its full service on 8 September.



## **TYPHOON TED (19W)**

### **I. HIGHLIGHTS**

As Typhoon Sibyl (18W) transitioned to an extratropical system and proceeded northeastward, a weak monsoon trough was becoming established to the north of the Caroline Island chain. A few days of respite ensued for JTWC while the disturbance that was to become Typhoon Ted slowly developed. Ted was marked by moderate to strong upper-level shear throughout most of its life, creating a cloud pattern which obscured the low-level circulation center rather frequently. A combination of shearing effects and land interaction prevented Ted from intensifying above minimal typhoon. Ted's tour of Asia included northern Luzon, northeastern Taiwan, eastern China, and finally Korea before the circulation transitioned to a weak extratropical cyclone over the Sea of Japan.

### **II. TRACK and INTENSITY**

On the 13 September Significant Tropical Weather Advisory, forecasters first noted the monsoon trough which would produce the circulation of Typhoon Ted. But, it was not until 16 September that a circulation became apparent. By 17 September, a TUTT-cell had become positioned to the northwest of the disturbance, enhancing its outflow, and organization began to significantly improve. A Tropical Cyclone Formation Alert was issued at 172030Z in response to an increase in convective curvature and a flare-up of convection coincidental with the convective diurnal maximum. In retrospect, the alert was about 18 hours behind the power curve. The first warning was issued by JTWC at 180000Z, and the depression initially proceeded west-northwestward. But, at 180600Z, the mid-level subtropical ridge became stronger and the system accelerated on a more westward course. Convective banding and organization continued to improve, and the system was upgraded to tropical storm intensity at 181800Z. Shortly thereafter, the first indication of significant shear over Ted was observed as the low-level circulation was consistently located under the eastern portion of the deepest convection (Figure 3-19-1). Between 191800Z and 201200Z, Ted slowed, and proceeded generally northwestward as a deepening low pressure system near Hokkaido, Japan temporarily weakened the low- to mid-level subtropical ridge. Ted resumed its westward track, and continued to slow as the system approached the westernmost extent of the ridge. At the surface, a high pressure system was building behind the low pressure system over Hokkaido and this wave pattern proceeded eastward rapidly. By 210000Z, all of the pieces were in place for Ted to proceed northward: 1) satellite imagery revealed a coupling between outflow from Ted and the mid-latitude frontal system; 2) as the high pressure system to the north of Ted moved eastward, pressures immediately north of Ted were falling; and, 3) synoptic data revealed that a weakness in the mid-level subtropical ridge became situated to the north of Taiwan. The reduced upper-level winds Ted encountered in the vicinity of the Luzon Strait enabled the system to briefly attain typhoon intensity (Figure 3-19-2), but at 220600Z, land interaction and increased upper-level wind flow caused Ted to revert back to tropical storm status where it remained until transformation to an extratropical low several days later. Ted accelerated during its northward transit until reaching 25 kt (46 km/hr) after recurvature. At 241200, Ted became extratropical and JTWC issued the final warning on the system.

### **III. FORECAST PERFORMANCE**

Systems which are consistently difficult to accurately locate generally produce the largest track forecast errors, and Ted was no exception. The initial acceleration of Ted south of the subtropical ridge was not forecast, but the acceleration was a relatively short-term phenomenon and did not severely



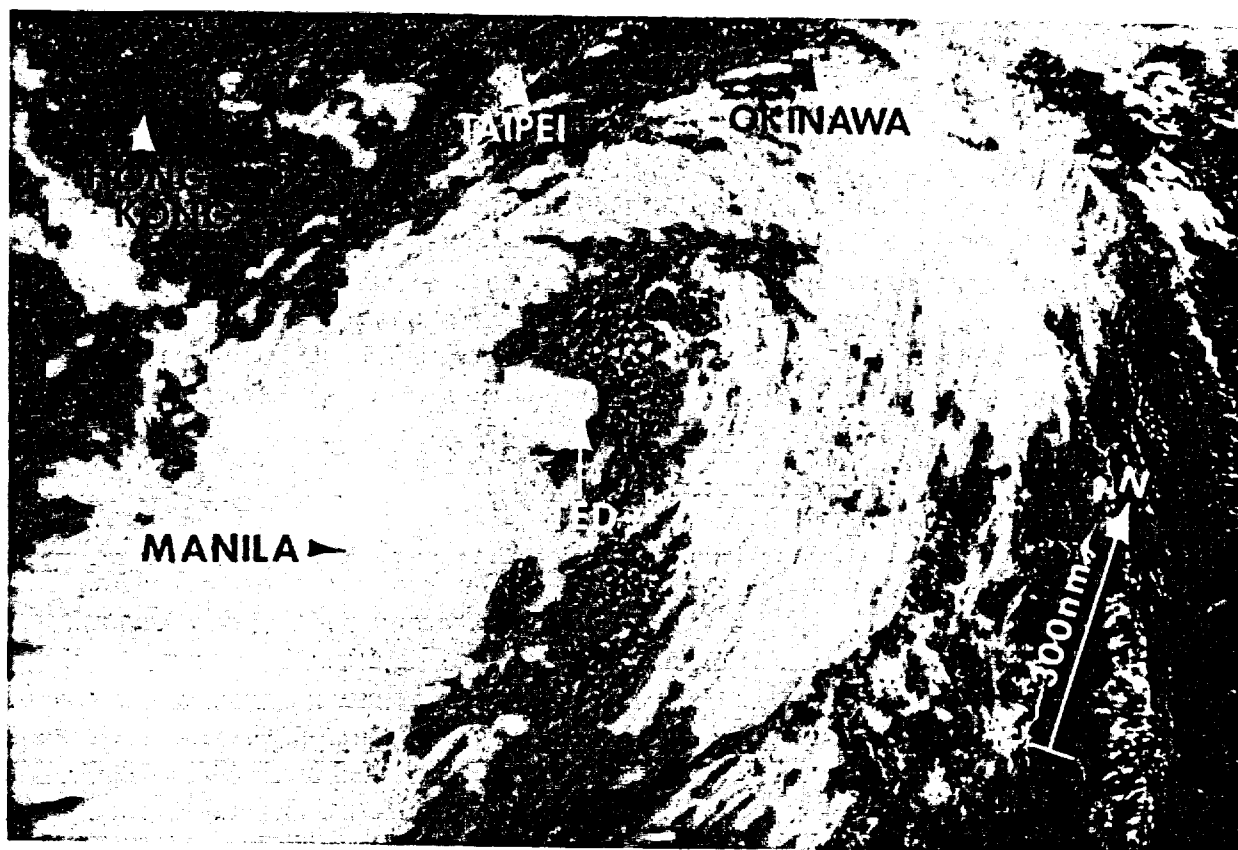


Figure 3-19-1. Tropical Storm Ted's low-level circulation is partially exposed as it approaches northern Luzon (200637Z September NOAA visual imagery).

impact the longer range forecast errors. JTWC forecasters lost faith in the NOGAPS numerical model early on as the model predicted slow northwestward to northward motion at the time Ted was transiting rapidly westward. As a result, forecasters relied heavily on persistence-and-climatological-based aids. After Ted turned north near Luzon, NOGAPS performed well, accurately predicting wave patterns in the mid-latitudes and the breakdown of the mid-level subtropical ridge near Taiwan. The premature lifting of a tropical cyclone to the north through a break in the subtropical ridge is typical of the NOGAPS or any model in general due to the coarse resolution. Once Ted entered the Luzon Strait, NOGAPS locked on to Ted's track (Figure 3-19-3). Tropical Storm Wendy in 1974 exhibited remarkably similar track characteristics, and was initially used by forecasters as an analog. It was recognized as an analog by forecasters only after northward movement in the Luzon Strait became apparent. The following forecast weaknesses were noted:

- 1) Over reliance on persistence and inadequate interpretation of flow patterns observed in satellite imagery and predicted by numerical models. For example: once Ted slowed to 4 kt (7 km/hr) in the Luzon Strait, forecasters hesitated in showing northward acceleration. The weakness in the subtropical ridge to the north was suggested by the linkage of convection between Ted and the mid-latitude frontal boundary on satellite images. Only when the speed had apparently increased to above 10 kt (19 km/hr), did JTWC forecasts indicated significant acceleration.

- 2) Failure to modify longer range intensity forecasts once it became apparent that upper-level shear would increase and remain persistent, and land interaction became inevitable. Some of the difficulty in this area could be attributed to the uncertainty in initial position of Ted at the various warning times, which inaccurately reflected the true motion over the previous 6- to 12-hour period.

#### IV. IMPACT

On northern Luzon, torrential rains from Ted caused landslides and flooding which resulted in at least 8 fatalities. The impact on Taiwan and eastern China was similar with heavy rains, flooding and landslides. However, the losses were much greater in eastern China where at least 53 lives were lost and as many people were reported as missing; over 30,000 houses collapsed; and extensive damage to agricultural land occurred. No loss of life or significant damage reports were received from Korea.

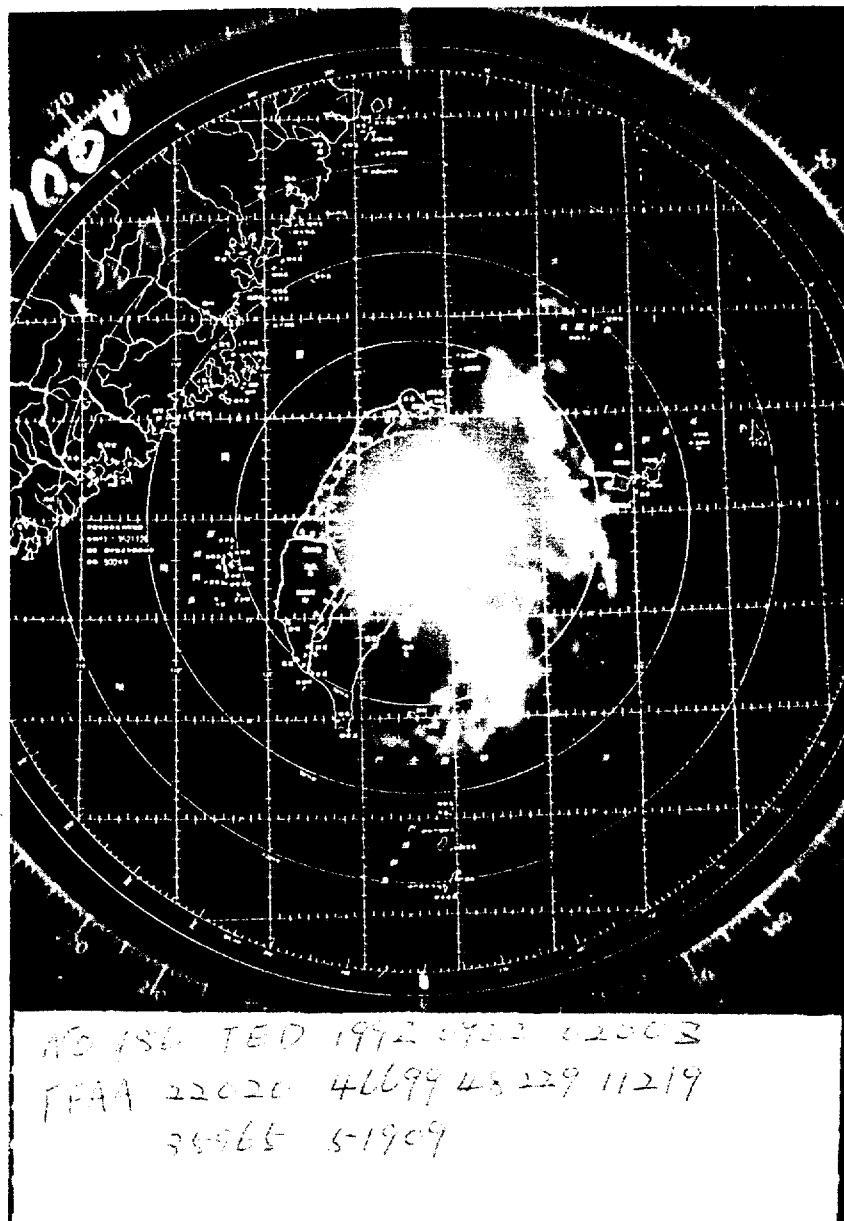


Figure 3-19-2. The 220200Z September radar image from Haulien (WMO 46699) of Ted at peak intensity (radar photo courtesy of the Central Weather Bureau, Taipei, Taiwan).

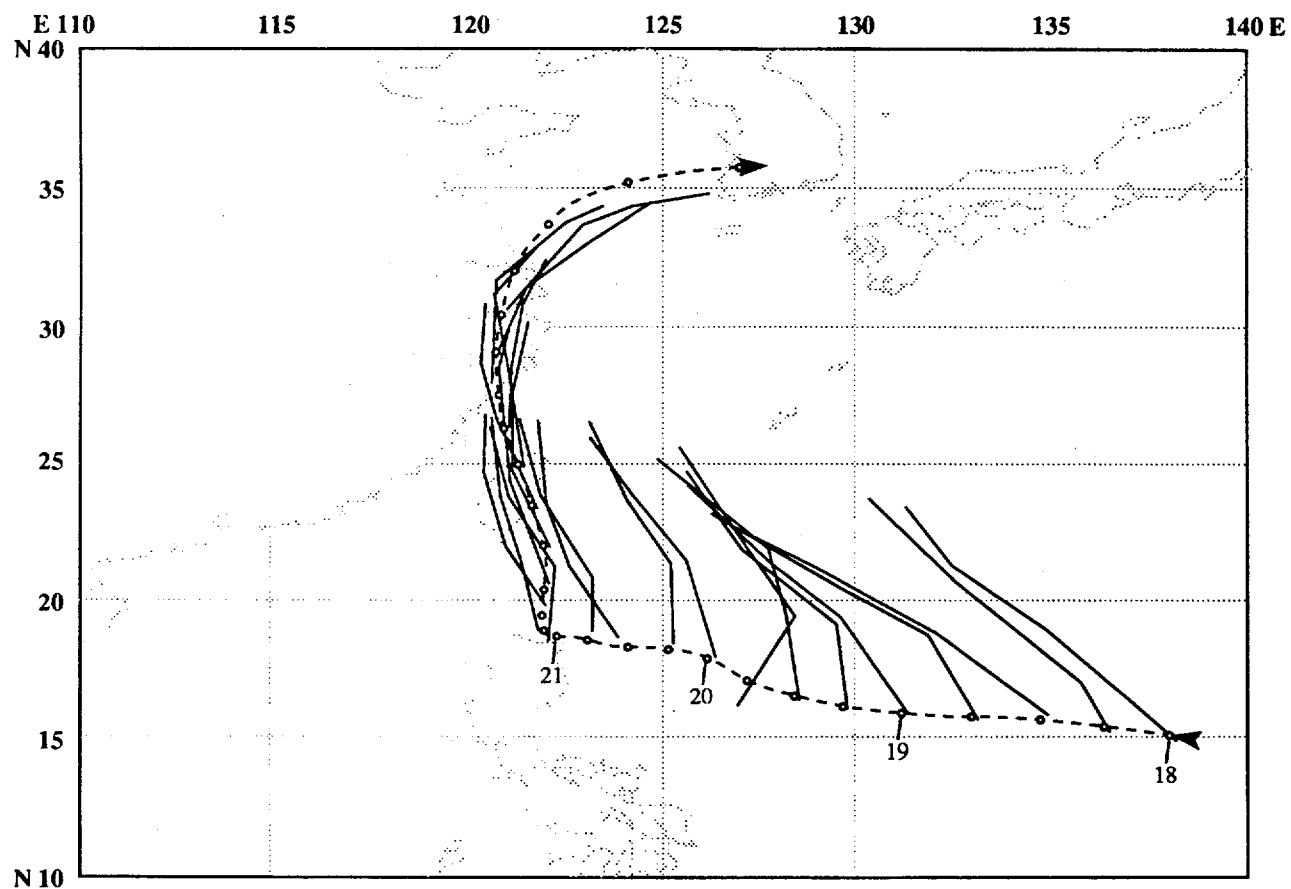
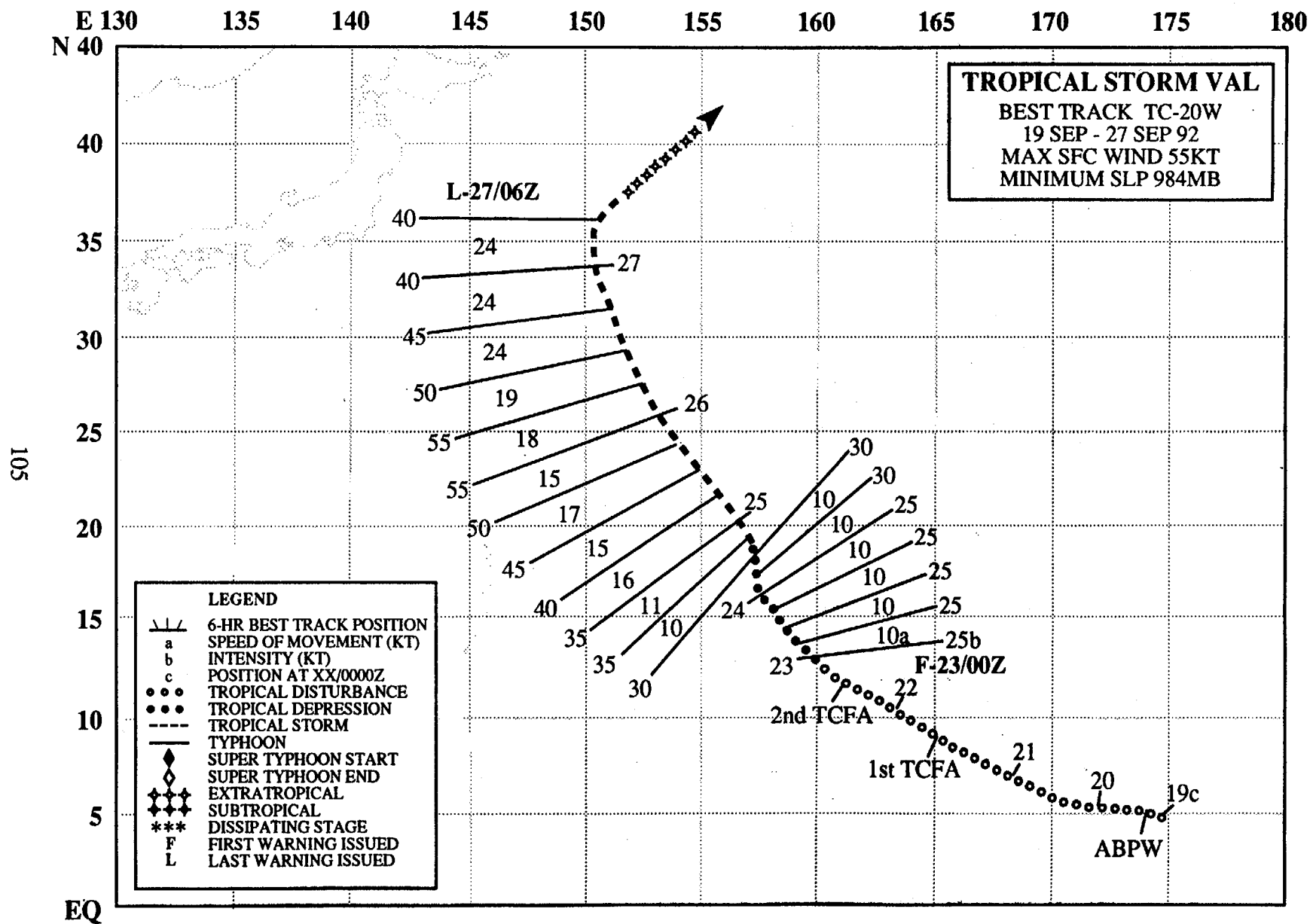


Figure 3-19-3. NOGAPS guidance for Ted is consistently north of track until the tropical storm enters the Luzon Strait, then the model locks on.



## TROPICAL STORM VAL (20W)

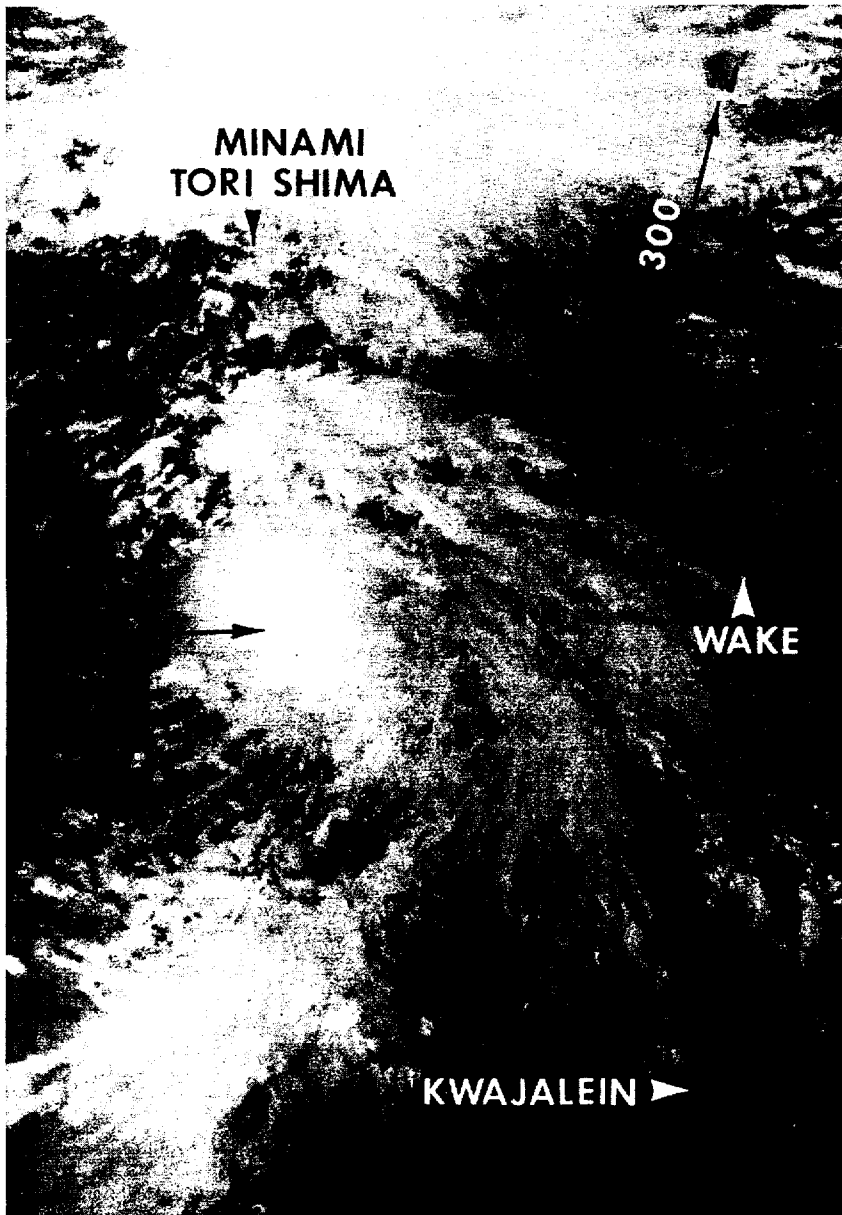
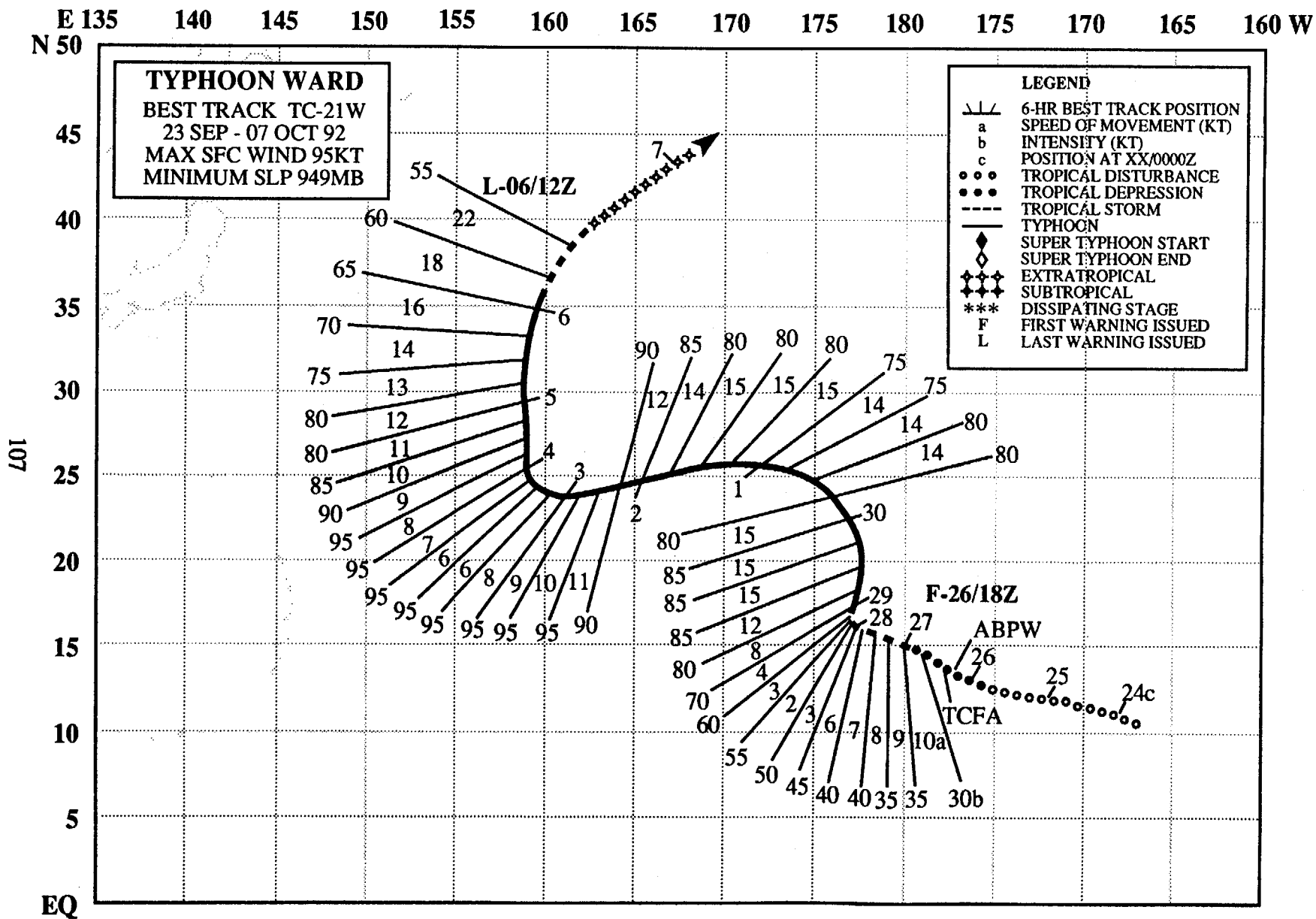


Figure 3-20-1. Poorly organized, but persistent convection defines Val 12 hours before it reaches tropical storm intensity (240406Z September NOAA visual imagery).

The fourth of five significant tropical cyclones to form in September, Val was the only one not to intensify beyond a tropical storm. Like Ted (19W), which formed a day earlier on 18 September, Val was slow to intensify. After first being mentioned as a broad area of convection on the 190600Z September Significant Tropical Weather Advisory, Val became the subject of two Tropical Cyclone Formation Alerts before the first warning. The tropical storm passed to the west of Minami Tori Shima, weakened, and on 27 September recurved. Val's transition to an extratropical low prompted JTWC to issue the final warning at 270600Z.



## TYPHOON WARD (21W)

### I. HIGHLIGHTS

The last of five significant tropical cyclones to form in September, Ward was unusual in that it underwent two major track changes and two significant acceleration episodes. As a result, it presented considerable difficulty to JTWC forecasters. Ward remained over open ocean its entire life and only posed a threat to maritime interests.

### II. TRACK and INTENSITY

Ward developed from a tropical disturbance that formed in the trade wind trough just to the east of the international date line. This disturbance was initially detected on 24 September when its persistent convection attracted the attention of satellite analysts collocated with JTWC. Even though the circulation was located east of the international date line, it was mentioned on the 260600Z September Significant Tropical Weather Advisory because it was anticipated to become a significant tropical cyclone as it crossed into JTWC's area of responsibility. At 261100Z, JTWC issued a Tropical Cyclone Formation Alert. Seven hours later, the first warning was issued at 261800Z, based on a satellite-derived intensity estimate of 30 kt (15 m/sec) and the presence of a well-defined low-level circulation center on the animated satellite imagery, near the area of deep convection. After being upgraded to a tropical storm, at 270000Z, Ward continued to track west-northwestward, gradually slowing down as it approached a weakness in the subtropical ridge which had developed in response to an approaching mid-tropospheric short-wave trough. On 28 September, the tropical storm turned sharply to the north and accelerated as the trough to the north swept past. Then, as the subtropical ridge strengthened to the north, Ward again made a sharp turn, this time to a more westward track. The appearance of a visible eye on 01 October indicated that the typhoon had begun to intensify a second time, reaching a maximum intensity of 95 kt (49 m/sec) at 021200Z. During the following 24 hours, the diameter of the eye expanded from 20 to 70 nm (37 to 130 km) (Figure 3-21-1).

On 5 October, a break in the subtropical ridge developed near 155°E longitude, allowing Ward to recurve and accelerate northward. Extratropical transition ensued on 6 October as the system moved over colder waters north of the Kuroshio current. JTWC issued its final warning at 061200Z.

### III. FORECAST PERFORMANCE

Ward's track proved to be difficult for JTWC forecasters to predict. Changes in the strength and orientation of the subtropical ridge led to two abrupt track changes, a series of deceleration and acceleration episodes, and a wide, arcing path as Ward's heading backed 130° from north-northeastward to west-southwestward between 29 September and 01 October. Typically, such a complex track would lead to larger than normal forecast errors, and this case was no exception. JTWC's overall mean track errors were 120, 255 and 360 nm (220, 470 and 665 km) for 24-, 48- and 72-hour forecasts, respectively. These results on average were 15% better than those of CLIPER, which provides the performance baseline for demonstrating skill. The primary reason for JTWC's acceptable performance was the guidance provided by the NOGAPS model which for Ward was impressive. However, this was not really appreciated until after the fact, when the overall mean track error for NOGAPS guidance was tabulated. It showed that NOGAPS bettered JTWC track forecasts at all time intervals except 12-hour forecasts. At 72-hours, the overall mean track errors for NOGAPS were 40% lower than JTWCs.

Overall intensity forecast errors were average; however, for a 2-day period starting at 300600Z, the 72-hour intensity forecasts were low by 15 to 30 kt (8 to 15 m/sec), as anticipated vertical shear did not occur to arrest intensification.

#### IV. IMPACT

Because Ward remained over open ocean during its lifetime, it only threatened maritime interests. No reports of any damage or loss of life were received.

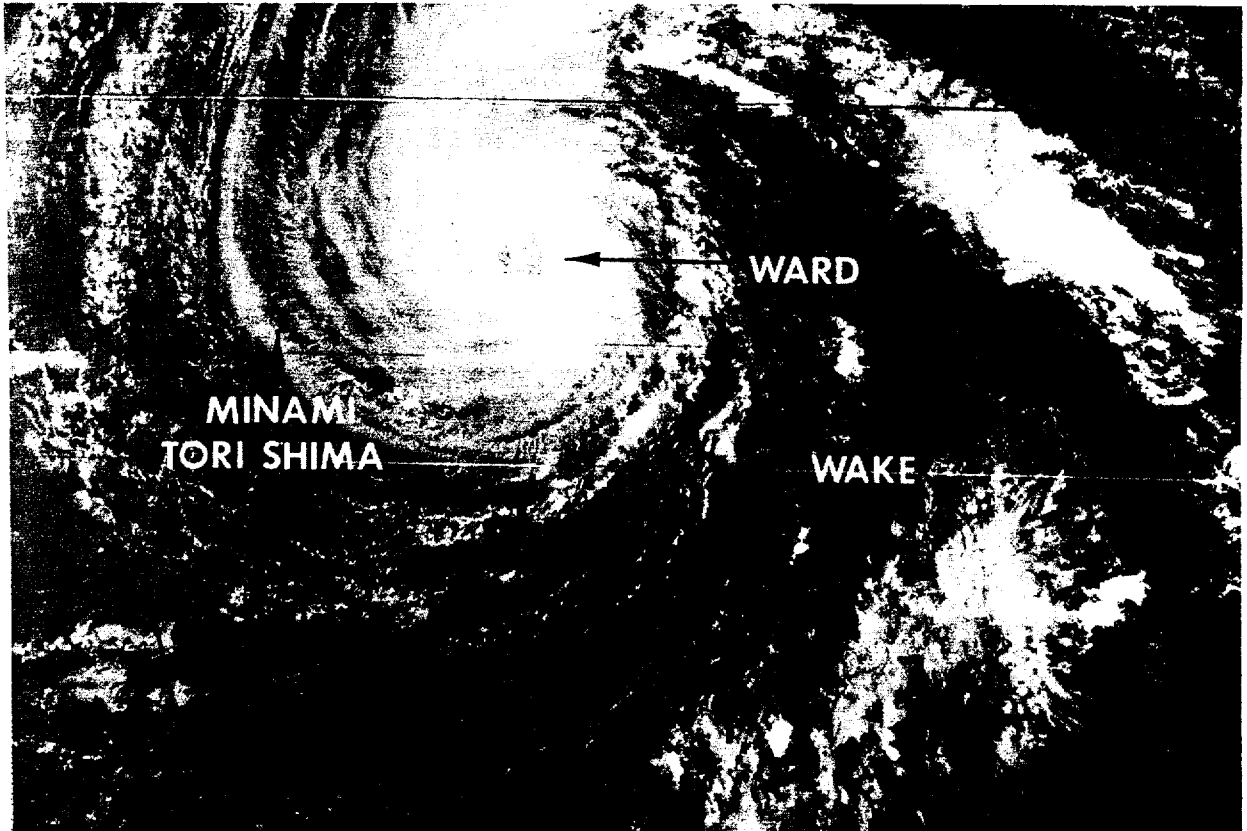


Figure 3-21-1. Ward's 55 nm (100 km) diameter eye is visible to the east of Minami Tori Shima (032232Z October DMSP visual imagery).



E 130 135 140 145 150 155 160 165 170 175 180

N 40

**TROPICAL STORM ZACK**  
 BEST TRACK TC-22W  
 05 OCT - 17 OCT 92  
 MAX SFC WIND 40KT  
 MINIMUM SLP 993MB

35

30

25

20

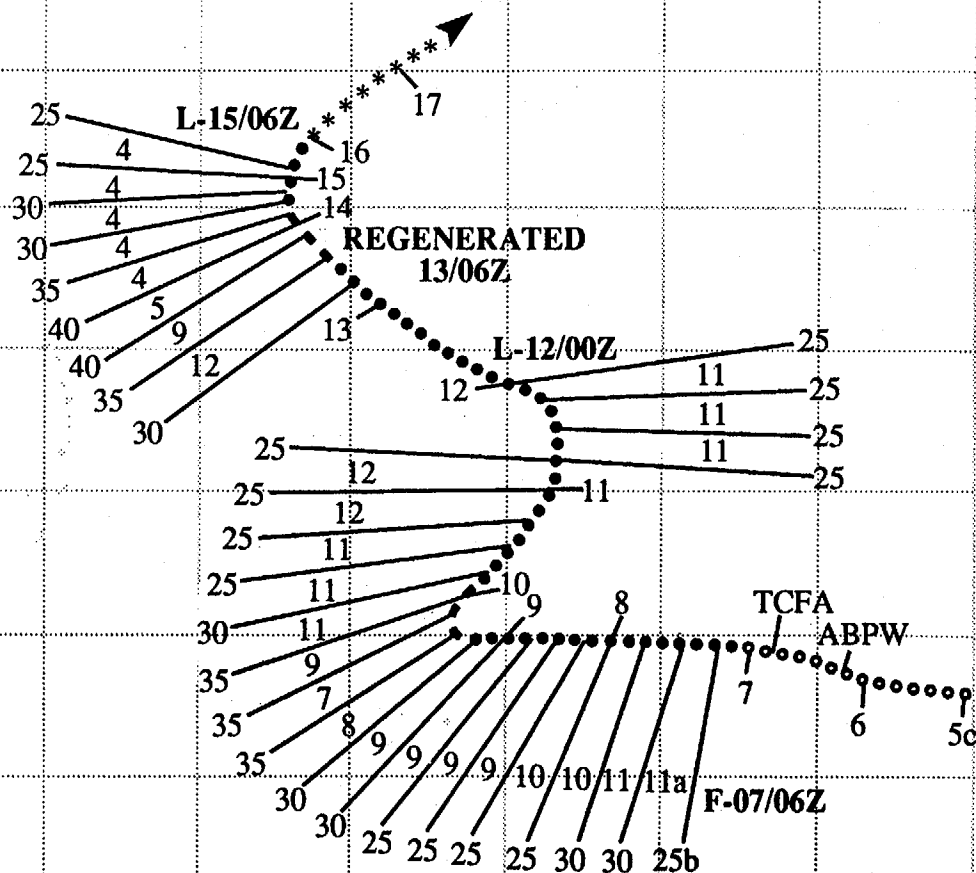
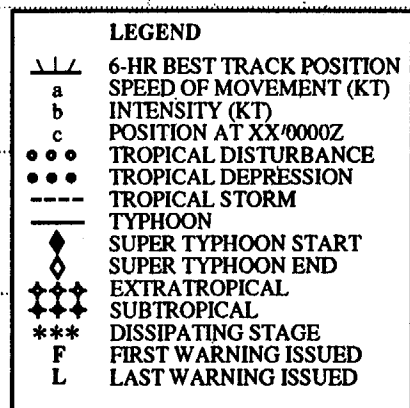
15

10

5

EQ

110



## TROPICAL STORM ZACK (22W)

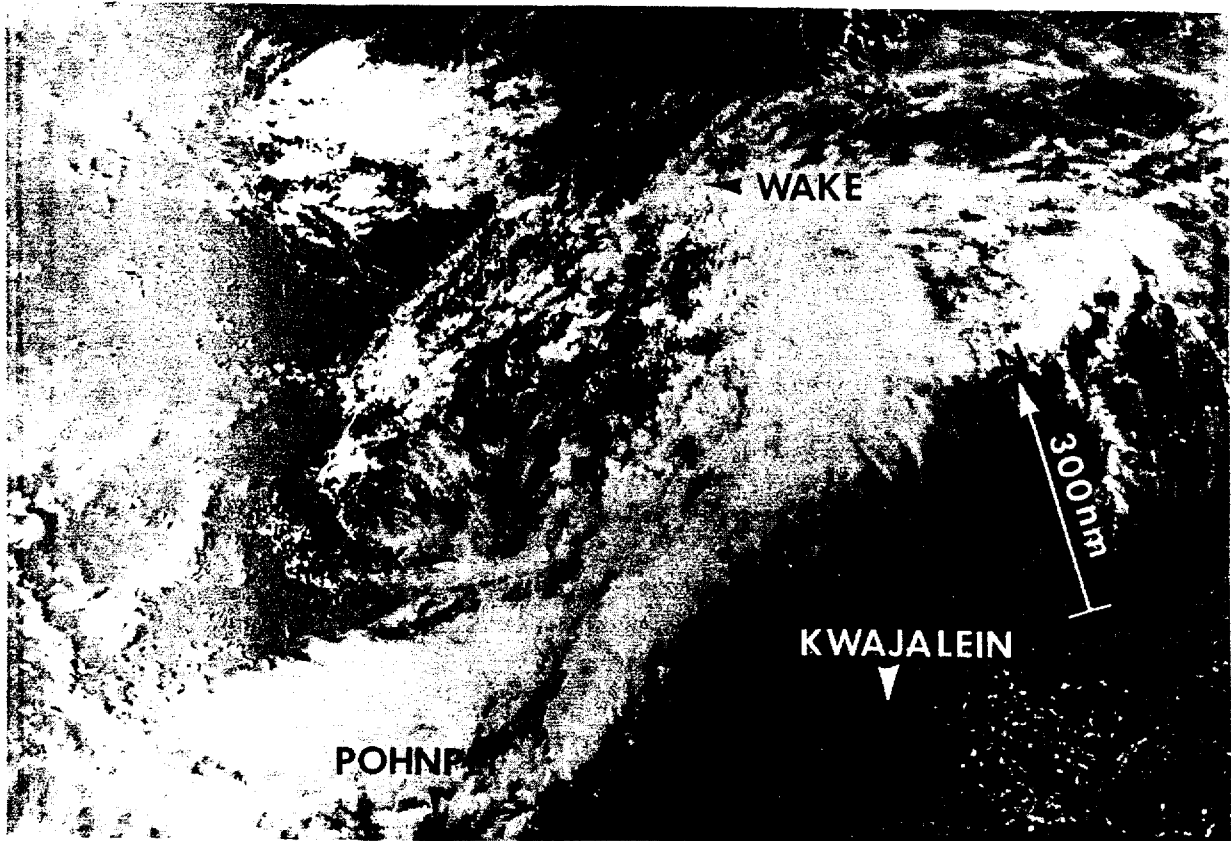
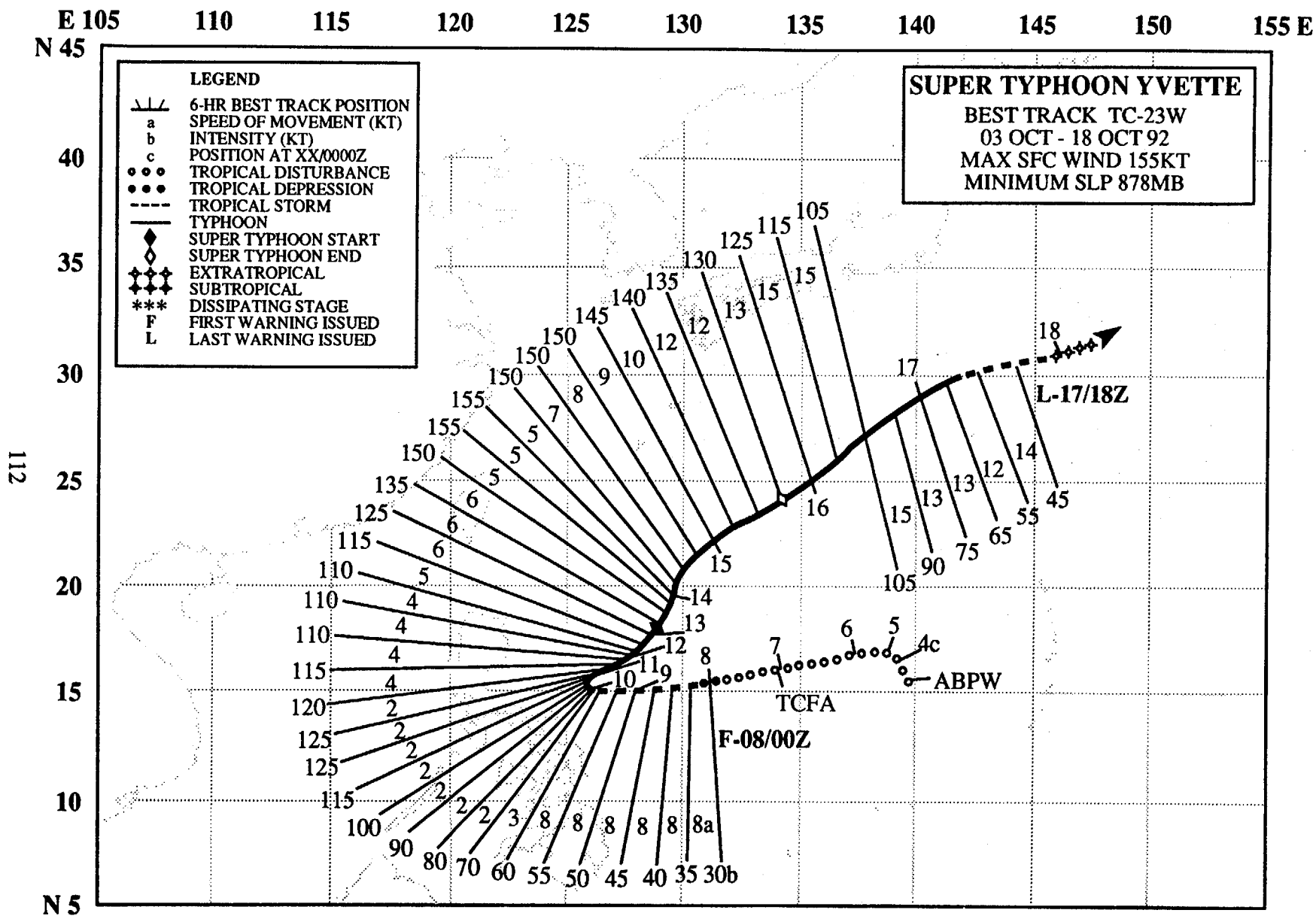


Figure 3-22-1. Cirrus cloud partially obscures Zack's exposed low-level circulation center, which appears at the western edge of a band of deep convective cloudiness associated with enhanced low-level southwesterly flow.

The first of eight significant tropical cyclones to form in October, Zack was also the first to threaten the southern Mariana Islands since Omar's (15W) devastating passage across Guam in August. Initial JTWC track forecasts towards the southern Mariana Islands and Guam were based on continued west-northwestward movement along the axis of the monsoon trough. On 9 October, however, a monsoon surge of deep southwesterly winds resulted in an abrupt track change to the north-northeast for Zack. As the tropical storm weakened, the low-level circulation center became difficult to locate, and JTWC issued a final warning on Zack at 120000Z. However, by the following day, the convection and organization of the system had increased, prompting JTWC to issue a "regenerated" warning at 130600Z. Zack briefly reintensified to a tropical storm before transitioning into a subtropical system and dissipating over the ocean. No reports of damage or injury were received.



## **SUPER TYPHOON YVETTE (23W)**

### **I. HIGHLIGHTS**

The third Northwest Pacific tropical cyclone of 1992 to achieve super typhoon intensity, Yvette was an action-packed system which posed many forecast challenges. In the span of two weeks, Yvette developed in a moderately sheared environment, made a run toward Luzon as it intensified to a typhoon, stalled, executed a major, 150-degree track change, weakened, reintensified to a super typhoon, and transitioned to an extratropical cyclone. This tropical cyclone marked the beginning of the 1992 super typhoon season - October being the month of most frequent super typhoon occurrence.

### **II. TRACK AND INTENSITY**

On 3 October, the monsoon trough extended from the South China Sea eastward across the southern Philippine Islands and Philippine Sea, through the southern Mariana Islands, and northeastward to Typhoon Ward (21W), located 1080 nm (2000 km) northeast of Guam. The persistence of convective activity along the trough in the Philippine Sea prompted JTWC forecasters to mention a broad tropical disturbance on the 030600Z Significant Tropical Weather Advisory. Due to moderate vertical wind shear, the low-level circulation center of this tropical disturbance, which was to become Yvette, remained poorly defined. On 5 October, the amount of convection started to increase around the center. At 070600Z, a Tropical Cyclone Formation Alert was released as the convective organization was rapidly improving. When a comma-shaped cloud mass developed in association with the center, JTWC issued the first warning for Tropical Depression 23W at 080000Z. With the rapid appearance of a central dense overcast, the system was upgraded to a tropical storm at 080600Z.

As Yvette tracked westward under the steering influence of the mid-level subtropical ridge to the north, it steadily intensified. At 091200Z, rapid intensification commenced with Yvette reaching typhoon intensity at 091800Z. The intensification process continued until the typhoon peaked at 125 kt (64 m/sec) at 110000Z (Figure 3-23-1). Coincident with the onset of rapid intensification, the typhoon virtually stalled and slowly executed a major track change to the northeast in conjunction with the subtropical ridge being weakened by the deepening and retrogression of the mid-level East Asian trough. After peaking, Yvette weakened slightly until 121200Z, when rapid intensification again started. This process of premature, low latitude recurvature and subsequent intensification has been described by Guard (1983). At the same time, a large plume of cirrus appeared, extending from the typhoon's central dense overcast to the frontal cloudiness to the north and northeast over Japan. By the time that Yvette had reached its maximum intensity of 155 kt (80 m/sec), at 131800Z, the extensive plume of cirrus to the northeast had almost disappeared, suggesting some relationship between the rapid intensification and the cirrus plume.

At 140600Z, the super typhoon (Figure 3-23-2) reached a position where it could proceed around the western end of the mid-level subtropical ridge. As vertical wind shear from southwesterlies aloft increased, Yvette's intensity decreased slowly until 16 October, then decreased more rapidly. At 171800Z, just before Yvette completed its transition to an extratropical low pressure system, JTWC issued the final warning.

### III. FORECAST PERFORMANCE

The overall mean errors for the track forecasts were 85, 190 and 340 nm (155, 355 and 630 km) for 24, 48 and 72 hours, respectively. These errors were essentially the same as those for CLIPER, which is used as a performance baseline. Problems that prevented JTWC from outperforming CLIPER were: 1) the stall and major track change from west to northeast when Yvette was approaching Luzon.

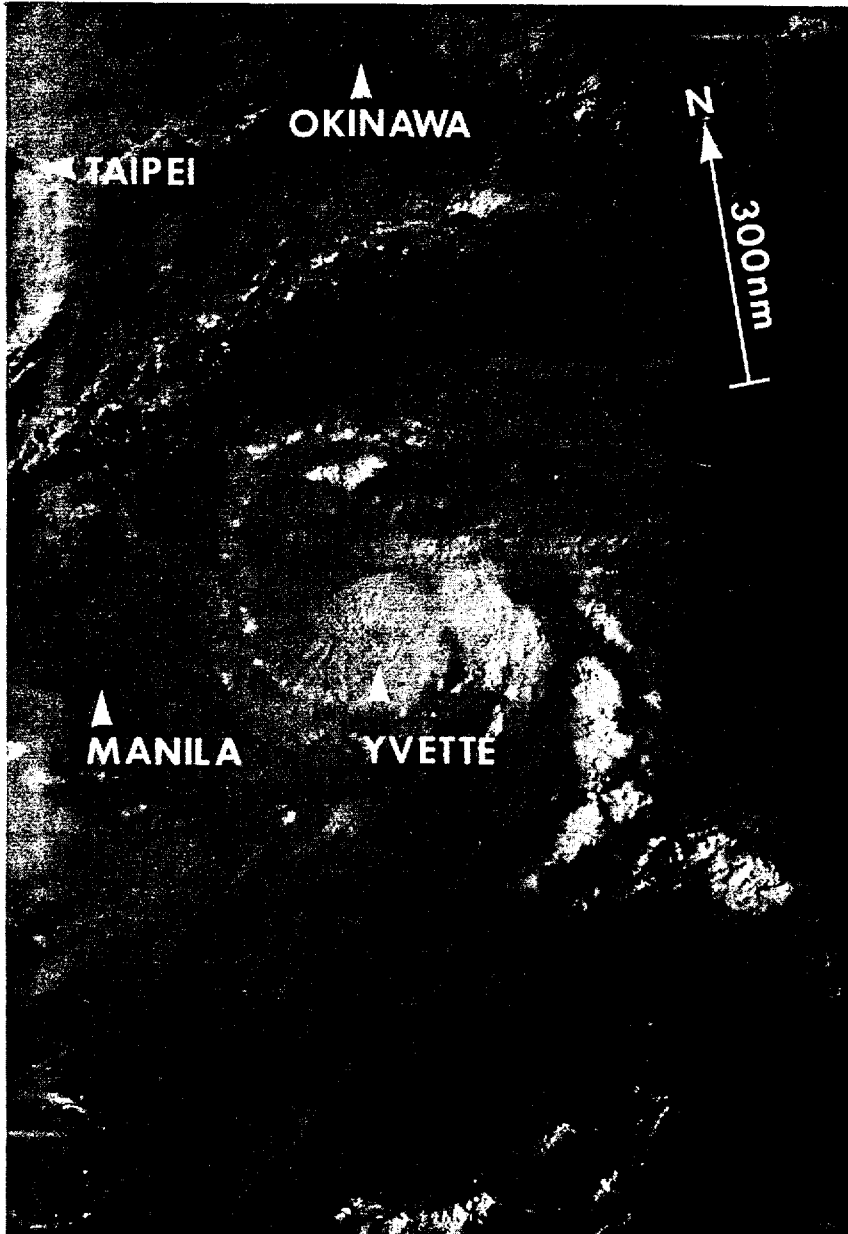


Figure 3-23-1. The tops of cumulonimbus embedded in Yvette's eye wall penetrate the cirrus overcast (100025Z October DMSP visual imagery).

The northeastward drift of Yvette was mentioned as an alternate scenario and then abandoned as the system appeared to be accelerating westward shortly before it stalled. This acceleration was not real, but resulted from differences between the raw satellite data based on poorly defined upper-level cloud top fixes and the location of the low-level circulation center, which was totally obscured by the high cloud shield; 2) the reintensification-to-super-typhoon episode was not considered as a possibility until six hours before it occurred. This was due primarily to an over-reliance on extrapolating the ongoing intensity trend into the future without any reliable intensity guidance from the numerical models to contradict that assumption; 3) the rapid rate of weakening, starting on 16 October, was under forecast again based on extrapolation of the earlier trend. In this case, numerical models did predict strong shear over Yvette but, it appeared to be a system that could remain intact much longer than it did in the presence of moderate-to-strong upper-level winds; and, 4) acceleration was over forecast during the period Yvette was becoming extratropical. This was caused by the slowing of the low-level circulation center after its decoupling from the from the mid- to upper-level center has occurred.

In retrospect and with regard to intensity forecasting, the first rapid intensification episode was successfully identified, before it occurred, based on the results of a study of tropical cyclone intensity climatology and application of a satellite pixel counting technique (Zehr, 1987).

The numerical model, NOGAPS, performed very well, identifying the exact longitude where Yvette would stall, and then its subsequent motion until it moved under strong mid- to upper-level wind flow on 11 October.

## VI. IMPACT

Super Typhoon Yvette remained over open ocean its entire life, and no reports of fatalities or damage were received at JTWC.

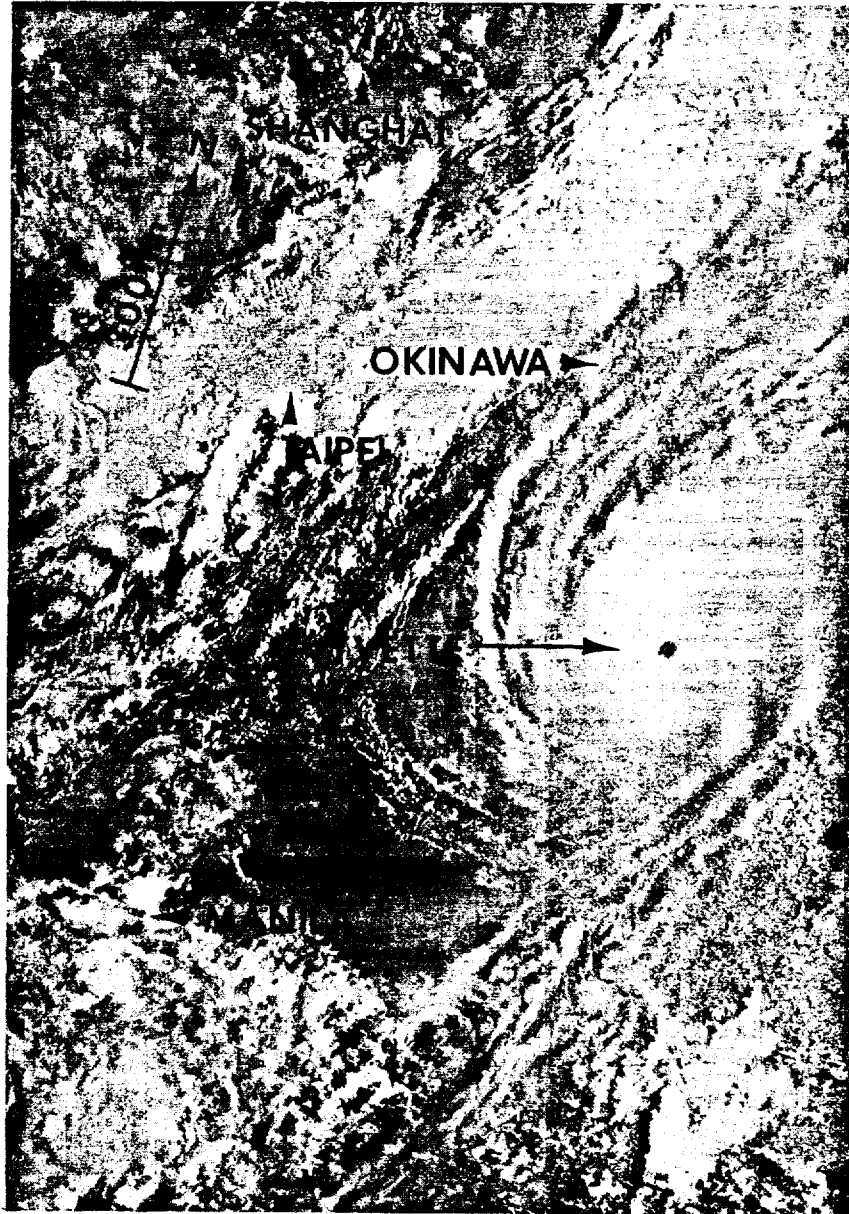


Figure 3-23-2. A moonlight image of Super Typhoon Yvette near peak intensity. Note the city lights of Shanghai, Taipei, Manila and of cities on Okinawa (141235Z October DMSP nighttime visual imagery).

E 85 90 95 100 105 110 115 120 125 130 E

N 35

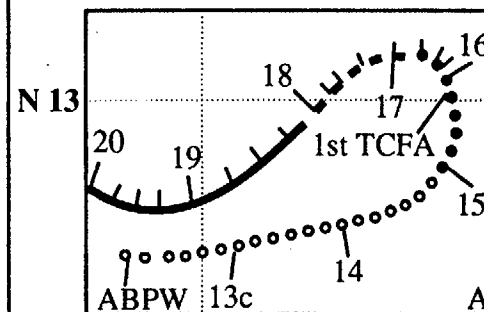
# **TYPHOON ANGELA**

BEST TRACK TC-24W  
12 OCT - 29 OCT 92  
MAX SFC WIND 90KT  
MINIMUM SLP 954MB

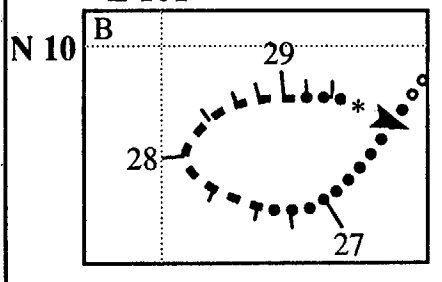
## **LEGEND**

- 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◆ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

E 115



E 101

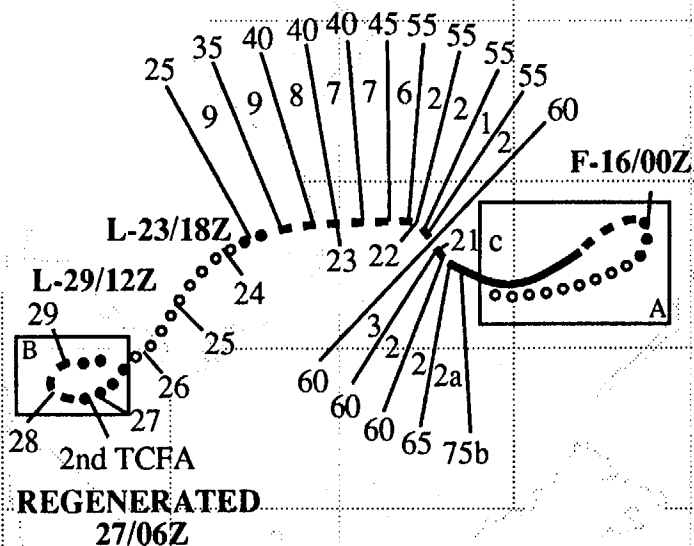


**B**

DTG	SPEED	INTENSITY
27/06Z	4	30
27/12Z	4	40
27/18Z	4	45
28/00Z	3	55
28/06Z	3	60
28/12Z	3	50
28/18Z	2	40
29/00Z	3	35
29/06Z	3	30
29/12Z	4	25

DTG SPEED INTENSITY

16/00Z	1	30
16/06Z	1	30
16/12Z	2	30
16/18Z	3	30
17/00Z	3	35
17/06Z	4	45
17/12Z	4	50
17/18Z	5	55
18/00Z	5	60
18/06Z	6	65
18/12Z	5	70
18/18Z	5	75
19/00Z	6	85
19/06Z	4	90
19/12Z	4	90
19/18Z	4	85
20/00Z	3	80



## **TYPHOON ANGELA (24W)**

### **I. HIGHLIGHTS**

The third of eight significant tropical cyclones to form in October, Angela developed in the South China Sea, moved east, reversed course and struck southern Vietnam, crossed southern Indochina, reintensified to a severe tropical storm in the Gulf of Thailand, tracked through a clockwise loop, and finally dissipated over water. While anchoring the western end of a monsoon trough, Angela became part of a four storm outbreak along with Brian (25W), Colleen (26W) and Dan (27W).

### **II. TRACK AND INTENSITY**

Developing in the South China Sea in the monsoon trough that trailed southwestward from Super Typhoon Yvette (23W), the tropical disturbance, which became Angela, was first mentioned on the 120600Z October Significant Tropical Weather Advisory as an area of persistent convection. The tropical disturbance drifted slowly eastward along the edge of the deep southwesterly flow on the south side of the trough. On 15 October, as Yvette (23W) reached the axis of the subtropical ridge and began recurving to the northeast, the vertical wind shear over the disturbance weakened. As a consequence, the disturbance began to intensify, prompting JTWC to issue a Tropical Cyclone Formation Alert (TCFA) at 151830Z, and the first warning at 160000Z.

With Yvette's (23W) departure from the tropics, the monsoon trough moved south to reestablish itself east-southeastward across the central Philippines and into the Caroline Islands. As this shift occurred, the orientation of the trough axis changed from southwest/northeast to east-southeast/west-northwest, and Tropical Depression 24W reversed course and slowly headed westward. Angela's further consolidation required JTWC to upgrade the 170000Z warning to tropical storm intensity, and later typhoon intensity at 180000Z.

By 18 October, Angela also became the anchor-low for the western end of the monsoon trough that extended eastward through Colleen (26W), Brian (25W), and into the southern Marshall Islands. As the northeasterly winds aloft increased, Angela's low-level circulation became partially exposed to the east of the deep central convection, and forecasters downgraded the typhoon to a tropical storm at 201800Z. Further weakening ensued as the tropical cyclone moved westward into southern Vietnam (3-24-1). This necessitated another downgrade to a tropical depression and, six hours later, a final warning at 231800Z, as the low-level center dissipated over land.

For the next four days the mid-level remnants of Angela persisted without central convection and moved southwestward across southern Indochina. Upon entering the Gulf of Thailand on 27 October, the cyclonic circulation slowly regained its convection and deepened through the lower troposphere. Another TCFA was issued by JTWC at 270330Z, and immediately followed by a regenerated warning on 270600Z. As the compact circulation of Angela intensified and began to execute a clockwise loop in the central Gulf of Thailand, it moved through a group of manned gas platforms which provided invaluable surface and radar reports. The reports from the Satun Station gas platform (9.3°N 101.4°E) proved to be important for describing the passage of this midget tropical cyclone. The 280240Z depiction of the Satun Station radar display in Figure 3-24-2 and the wind reports (Figure 3-24-3), which included the 70 kt (36 m/sec) peak at 280440Z, prompted JTWC forecasters to upgrade the 280600Z warning to typhoon intensity. Later, during post analysis, this 6-hour maximum at typhoon intensity was reduced to a severe tropical storm intensity of 60 kt (31 m/sec) based on the relatively high surface pressures near 1000 mb, other wind reports in the area, and the determination that the 70-kt



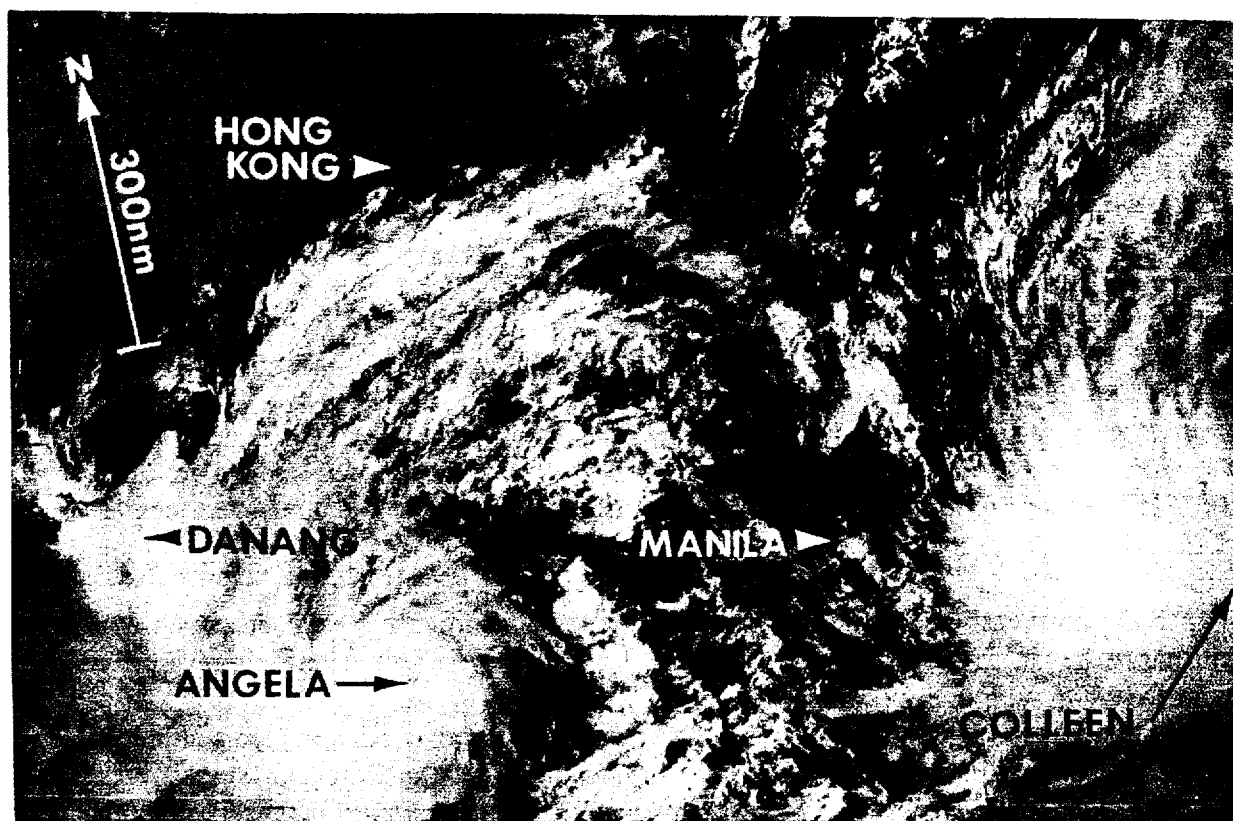


Figure 3-24-1. Twelve hours after being downgraded to a tropical storm, Angela churns westward across the South China Sea towards southern Vietnam. Part of Colleen's (26W) dense overcast is visible at the lower right of the picture (210122Z October DMSP visual imagery).

wind report was averaged over a period of less than one minute. After this peak, Angela's organization and intensity rapidly weakened due to upper-level wind shear until the "second" final warning was issued by JTWC at 291200Z as the tropical cyclone dissipated over the Gulf.

### III. FORECAST PERFORMANCE

The overall mean track forecasting errors showed that JTWC's performance was better than average and showed skill in comparison with CLIPER, which is used as the baseline for performance. With overall errors of 80, 145 and 180 nm (145, 265 and 330 km) at 24, 48 and 72 hours, respectively, JTWC bettered CLIPER's performance by 30%. Initially, due to the relatively weak steering flow affecting Angela, track forecast guidance was poor. However, once Angela began to move westward toward the Vietnamese coast, most forecast aids did well. Later, in the Gulf of Thailand, the track guidance tended to track Angela across the Malay Peninsula and into the Bay of Bengal.

### IV. IMPACT

In southern Vietnam, at least seven people were reported missing and 17 others injured. Angela's torrential rains caused extensive flooding, loss of crops, livestock and fishing boats, and damage to rail lines and roads. In Thailand, there were two fatalities and seven people were reported missing. Heavy rains and flooding resulted in at least 600 houses being destroyed. Angela posed a significant threat in the Gulf of Thailand, where manned gas platforms were forced to evacuate as Angela intensified and moved into the area. All platform evacuations proceeded smoothly and no reports of damage or injuries were received.

The weather and radar reports from the manned gas platforms in the Gulf of Thailand presented forecasters at JTWC a unique opportunity to gather data on the rainbands and compact wind field associated with a very small tropical cyclone.

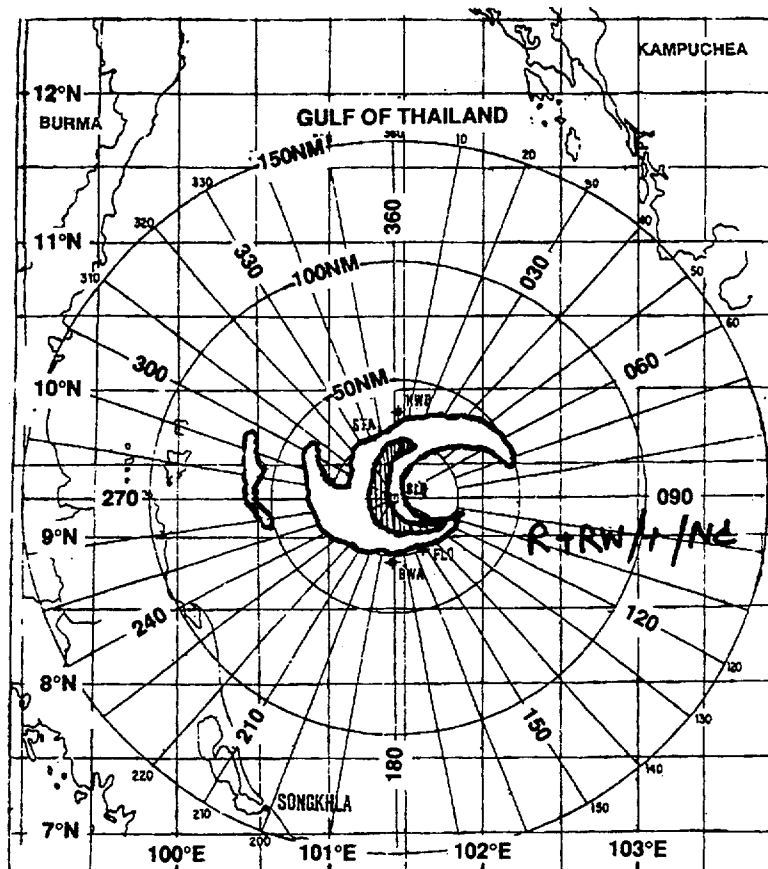


Figure 3-24-2. Angela's tightly curved rainbands as seen on radar from the Satun Station gas platform located at 9.3°N and 101.4°E (radar depiction courtesy of UNOCAL Thailand, Ltd.).

28 OCTOBER 1993								
Time (Z)	00	01	02	03	04	05	06	07
Pressure (mb)	1002.3	1001.5	m	m	998.1	1000.1	1001.9	1000.9
Wind (kt)								
Wave Height (m)	5.2	5.3	m	m	6.2	5.0	5.0	3.9

Figure 3-24-3. Wind reports which are plotted to the nearest hour for the Satun Station gas platform (9.3°N, 101.4°E) for the 24-hour period commencing 270900Z. Angela's passage close by the platform is reflected by the storm force winds, wind shift, and lower pressures from 280300Z to 280600Z. The lowest pressure reported was 998.1 mb at 280400Z, however, the pressure an hour earlier, which was missing from the data set, could have been considerably lower (data courtesy of Uncope Thailand, Ltd.).

E 120 125 130 135 140 145 150 155 160 165 170 175 180

N 40

35

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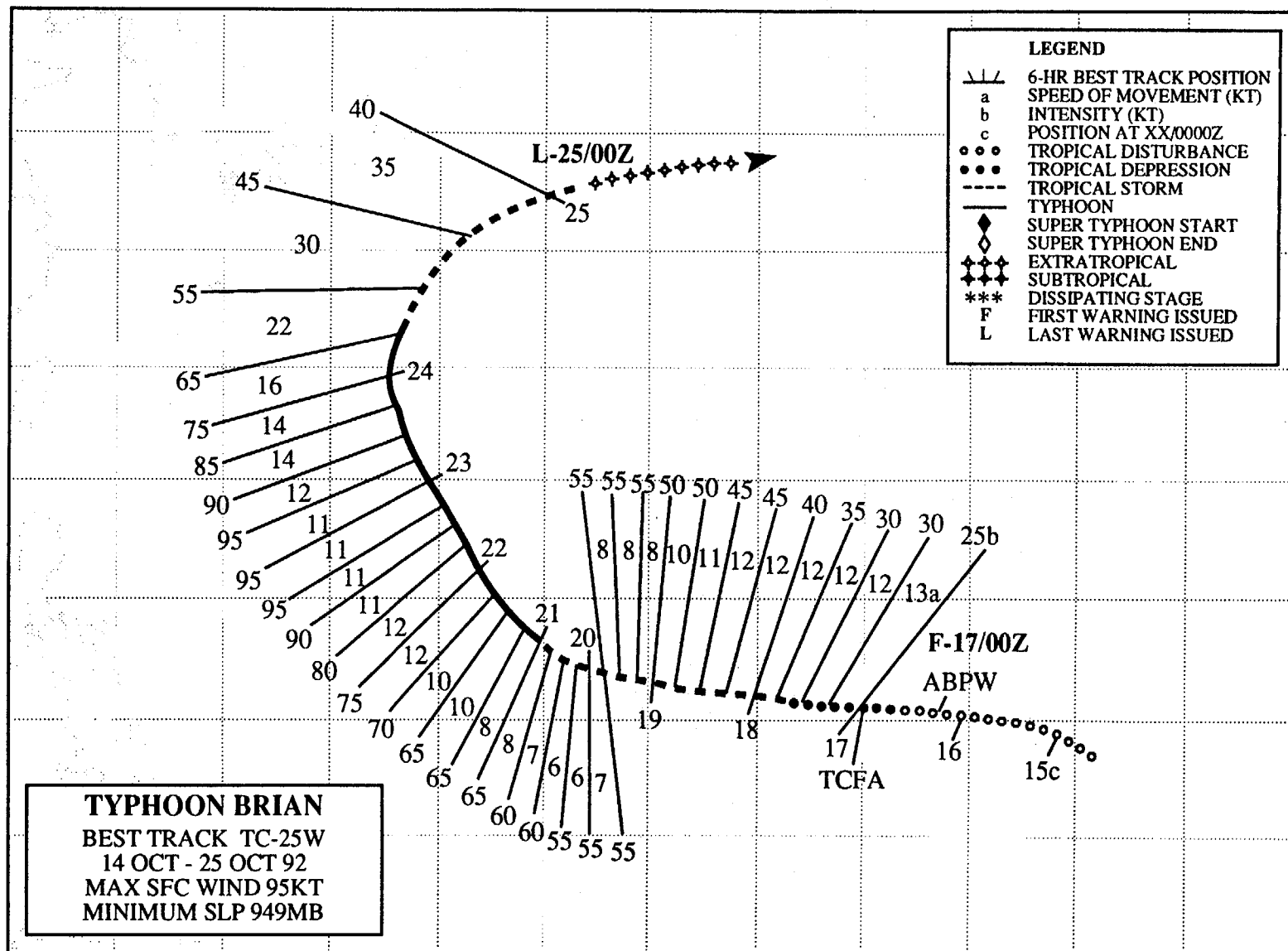
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## TYPHOON BRIAN (25W)

### I. HIGHLIGHTS

Brian was part of the four storm outbreak in October that included Angela (24W), Colleen (26W) and Dan (27W). Forming in the southern Marshall Islands, Brian moved west-northwestward and intensified to a typhoon as it passed across Guam. For Guam, it was the second eye passage in less than two months - Omar (15W) was the first. Later, Brian underwent binary interaction with Typhoon Colleen (26W), subsequently recurved, and finally transitioned to an extratropical system.

### II. TRACK AND INTENSITY

JTWC began monitoring the tropical disturbance, that would become Typhoon Brian, in the southern Marshall Islands on 14 October. After an increase in the amount and organization of the cloudiness, the tropical disturbance was mentioned on the 161600Z Significant Tropical Weather Advisory. Initially the potential for development was considered to be poor. However, a rapid increase in convection prompted JTWC to reissue the Advisory at 161800Z, and the area's potential for development was upgraded to fair. A Tropical Cyclone Formation Alert followed at 162223Z as organization continued to improve. Anticipating continued consolidation within the small compact cloud system, and assessing the potential for subsequent rapid intensification as good, JTWC issued the first warning at 170300Z.

The tropical cyclone was upgraded to Tropical Storm Brian at 171800Z. As it approached Guam, Brian's convection increased markedly during the nighttime hours. With no synoptic data reports near the center of the small circulation and impressive convective flare-ups for two nights running on the satellite imagery, there was a question on the second night: "Was rapid intensification taking place or not?" When satellite data gave conflicting information concerning the intensity of the storm, JTWC elected to go with the higher intensity that indicated that rapid intensification was occurring. Subsequently, Brian was upgraded to typhoon intensity at 190600Z based on the higher satellite intensity estimates. As the tropical cyclone approached Guam on the morning of 21 October, it became apparent that Brian was a smaller than expected system, and that its intensity and area affected by the high surface winds were significantly less than forecast. Brian was, in fact, a midget typhoon with 65-kt (33-m/sec) sustained winds.

The extended outlook for the track was more straight forward. For two days prior to Brian hitting Guam, JTWC predicted a direct hit. As Brian approached Guam, fixes from satellite imagery and the Federal Aviation Administration flight control radar at Mount Santa Rosa showed that as the tropical cyclone slowed, it began to exhibit erratic motion. Despite the erratic motion, JTWC continued to predict a direct hit, and actually pin-pointed the southern half of the island as the target. The leading edge of the small, 10 nm (19 km) diameter eye came ashore just northeast of DanDan at 202350Z, and later exited near Orote Point at 210300Z (Figure 3-25-1).

As Brian's eye came across Guam, an interesting phenomena was observed by residents on the west side of the island from Orote Point northward to Taguac. Preceding the onset of the primary area of light-and-variable winds within the eye, there was another low pressure area — a precursor — where the winds lessened prematurely and the sky lightened. This precursor event was followed by a band of heavy rain and wind. Figure 3-25-2 illustrates the merge of the leeside low with the eye of Brian. The event appears on the Nimitz Hill microbarograph trace (Figure 3-25-3) as a drop in pressure (at Point A) followed by a rise in pressure associated with the squall, and then another drop in pressure (at Point B).

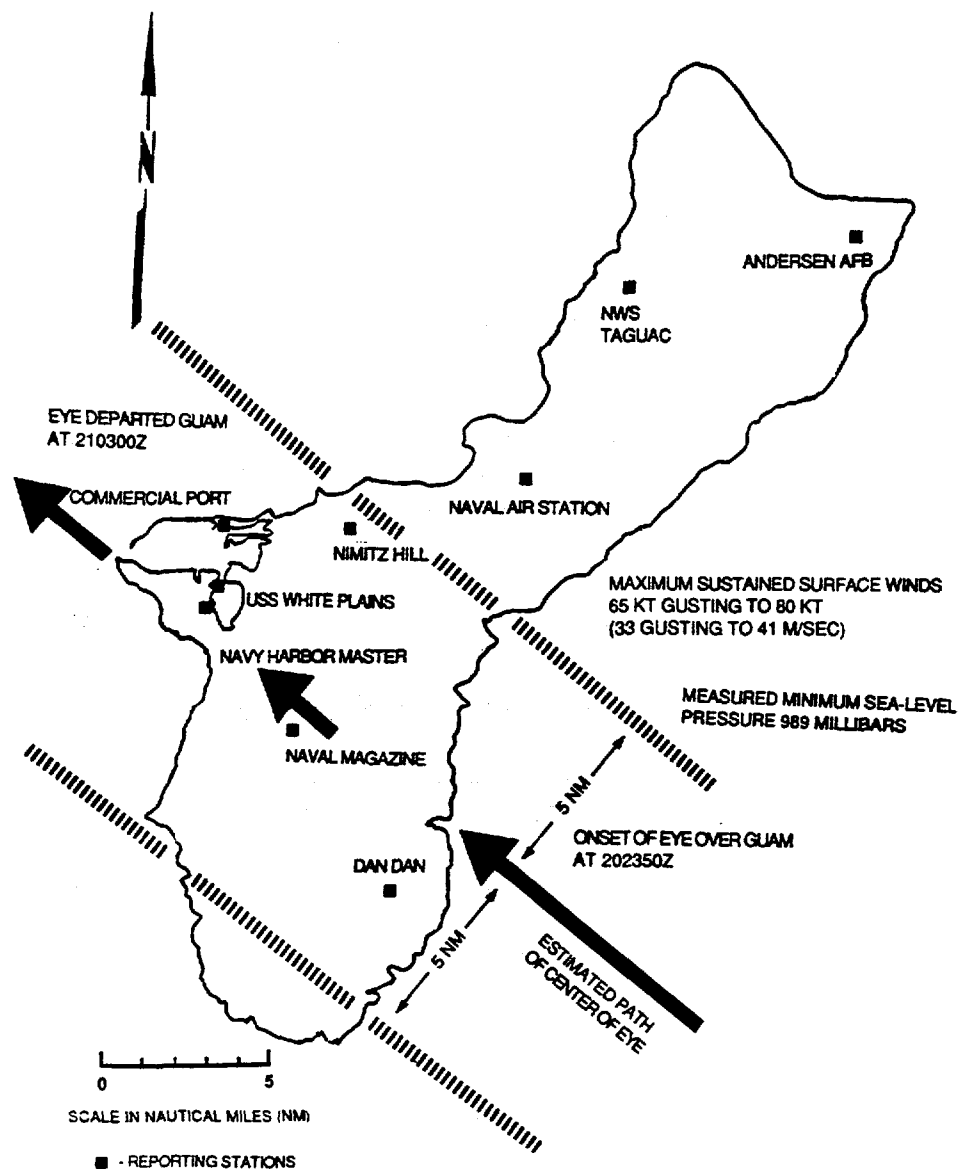


Figure 3-25-1. Graphic of Brian's 10 nm (19 km) diameter eye passage across Guam on 21 October.

What is suggested was that Brian, which was small and at minimal typhoon intensity, encountered a barrier, the island of Guam, in its path. The wind field within the core region adjusted to the barrier and a lee side low, or secondary circulation, formed ahead, and to the west of, the primary circulation center. As the eye approached, the lee side low shrunk in size, consolidating over the northwest portion of Guam. Once the eye moved to the west side of the island, strong low-level winds trying to flow toward the low pressure of the eye quickly returned to normal, and Brian regained its more normal form and intensified. During this time, Guam's maximum sustained 1-minute winds of 65 kt (33 m/sec) gusting to 80 kt (41 m/sec) were recorded at Nimitz Hill, which is 650 feet (200 m) above sea level. Typhoon force winds may also have occurred in the east coastal areas, but the no wind recording were available at these locations. The minimum sea-level pressure reading of 989 mb was recorded in the eye by the

fast supply ship **U.S.S White Plains**, which was moored in Apra Harbor. While this pressure is too high to support typhoon-force winds for a normal sized tropical cyclone, computations indicate that it was sufficient to support typhoon-force winds for a cyclone the size of Brian

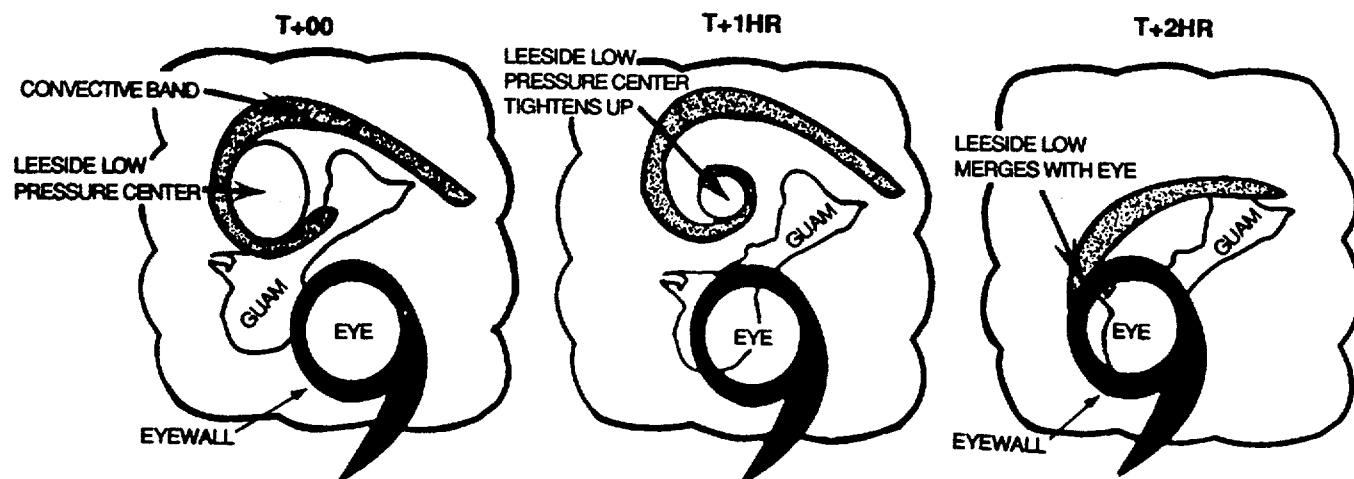


Figure 3-25-2. Sequence of events illustrating the merger of a low on the leeward side of Guam with the eye of Brian.

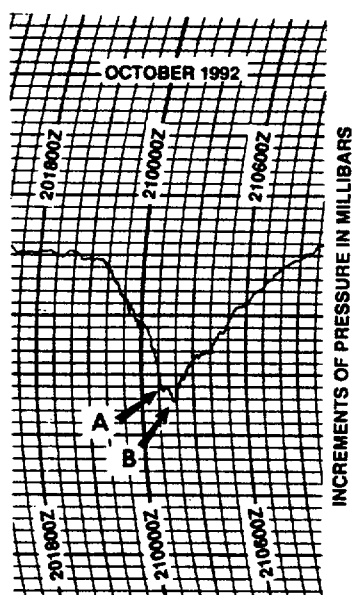


Figure 3-25-3. Microbarograph trace from the Nimitz Hill, Guam during the passage of Typhoon Brian. Point A is the passage of the leeward low that preceded the passage of the eye at point B.

On 21 October, as Brian moved into the Philippine Sea, it became involved in a binary interaction for the next three days with Typhoon Colleen (26W) which was located to the west (Figure 3-25-4). Brian peaked at 95 kt (49 m/sec) at 221800Z, and on 24 October, the typhoon recurved south of Japan, accelerated, and transitioned to an extratropical low. The final warning was issued by JTWC at 250000Z.

### III. FORECAST PERFORMANCE

The overall mean track errors for JTWC were 90, 140 and 225 nm (170, 255 and 415 km) for the 24-, 48- and 72-hour forecasts, respectively. These were 25-42% lower than JTWC's long term average and approximately 25% better than those of CLIPER, which is used as a baseline for determining skill. Typhoon Colleen (26W), which was about 1000 nm (1850 km) to the west of Brian, added a measure of difficulty and uncertainty to both the intensity and track forecasts for Brian. Colleen's outflow aloft blew eastward across Brian and impeded the formation of Brian's upper level anticyclone, which may have slowed the intensification of Brian's midlevel circulation. Also, the induced ridging between the two cyclones probably contributed to the slowing and erratic motion of Brian's track as it neared Guam. Finally, the binary interaction between the typhoons was of significant concern until Brian recurved.

In contrast to the track forecasts, the intensity forecasts were poor. For a four day period starting at 171800Z, the 72-hour outlooks were consistently 25 to 55 kt (13 to 28 m/sec) too high. And for two days before Brian crossed Guam, the initial warning intensities were determined to be 25 to 35 kt (13 to 18 m/sec) high. The high intensity forecasts for four days resulted from anticipation of rapid intensification that did not occur, and were compounded, for two of the four days, by high values for intensity on the initial warnings.

### IV. IMPACT

Damage on Guam was much less than would have occurred had Typhoon Omar not hit less than 2 months earlier. Omar destroyed most structures that a weaker storm might have damaged or destroyed. Schools and businesses were closed for two days as the typhoon passed. Some power lines were blown down, and there were isolated reports of damage in the central portion of the island. The agriculture industry suffered the most, as the coastal regions received considerable salt water spray damage.

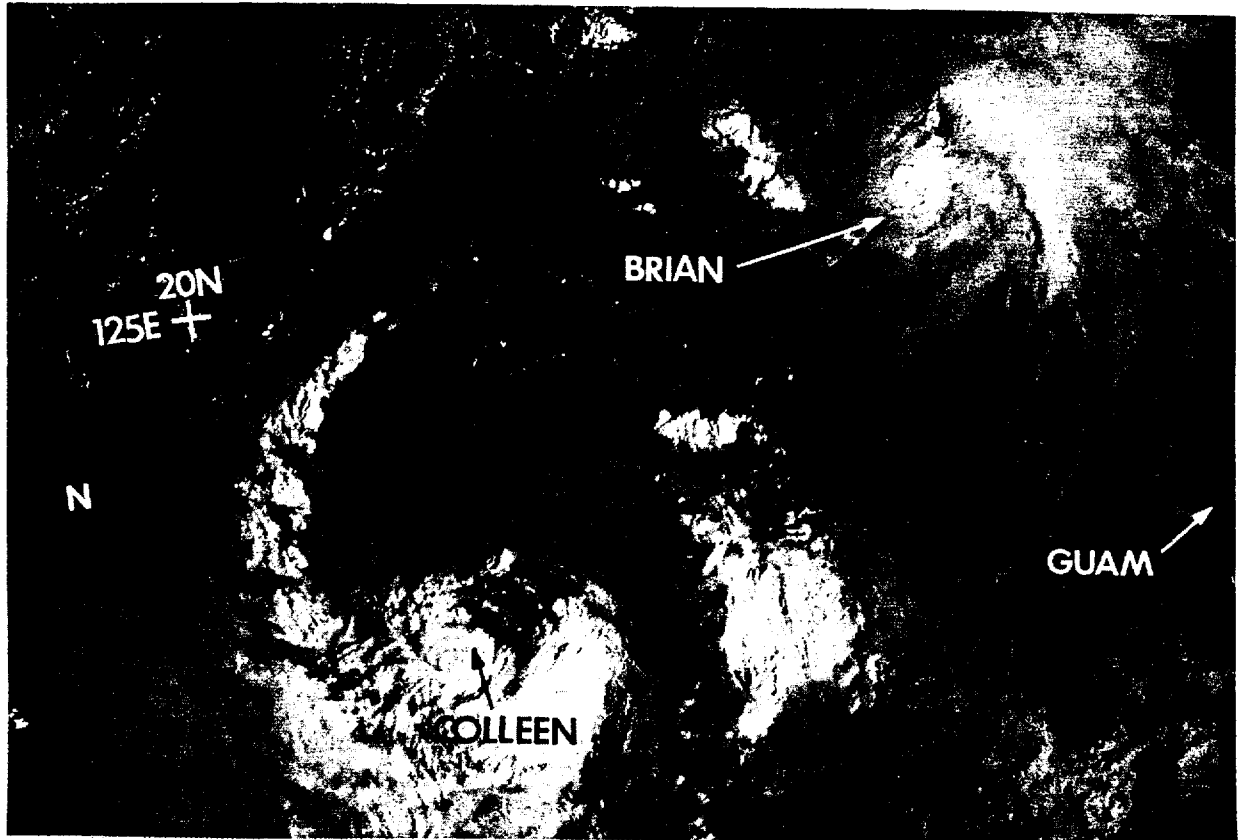
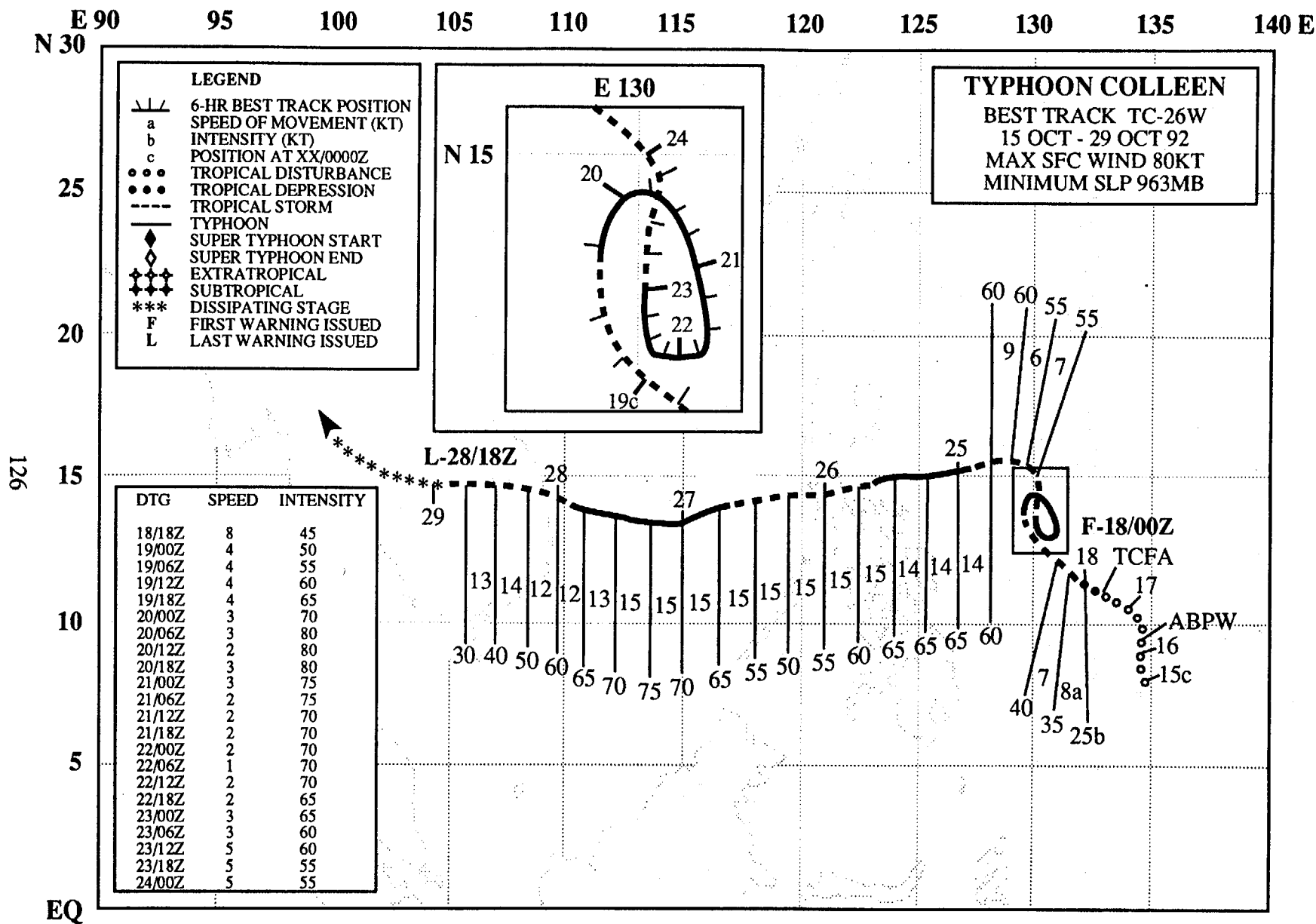


Figure 3-25-4. Brian undergoes binary interaction with Typhoon Colleen (26W) (230019Z October DMSP visual imagery).





## TYPHOON COLLEEN (26W)

### I. HIGHLIGHTS

The third significant tropical cyclone to form as part of the four storm outbreak in mid-October, Colleen developed from a broad cyclonic circulation in the monsoon trough between Typhoon Angela (24W) to the west and Typhoon Brian (25W) to the east. Binary interaction occurred between Colleen and Brian (25W), causing Colleen to make a slow anticyclonic loop in the Philippine Sea before turning west. After crossing Luzon, Colleen reintensified to a typhoon before slamming into central Vietnam and dissipating inland.

### II. TRACK AND INTENSITY

Anchored by what was to become Typhoon Angela (24W) in the South China Sea, the monsoon trough extended eastward into the southern Marshall Islands where Typhoon Brian (25W) was developing. The weak low-level circulation, that was to become Colleen, formed in the monsoon trough in the Philippine Sea and was first mentioned on the Significant Tropical Weather Advisory at 160600Z. A Tropical Cyclone Formation Alert was issued by JTWC at 171600Z based on the increased cloud organization in satellite imagery of the disturbance and increasing gradient-level winds at Koror (WMO 91408). Continued intensification during the morning prompted JTWC to issue the first warning at 180000Z. Only six hours later, JTWC upgraded Tropical Depression 26W to Tropical Storm Colleen. But, Tropical Storm Colleen went through several reorganization periods over the first few days as its broad circulation became more vertically aligned. The upper-level flow was shearing the convection to the west while the southwesterly surface flow associated with the monsoon trough forced the low-level to track and reorganize to the east. Despite the strong shear, the cyclone continued to consolidate, and JTWC upgraded Colleen to typhoon intensity on the 191800Z warning.

With regard to the episode of binary interaction, Colleen and Brian (25W) had been, in a relative sense, approaching each other since 15 October (Figure 3-26-1). It became apparent that capture of the two circulations had occurred at 201200Z when they began to orbit around a common point, or centroid (Figures 3-26-2 and 3-26-3). On 22 October, the binary pair reached a minimum separation distance of 680 nm (1260 km). During the binary interaction, Colleen, the larger of the two cyclones, slowed and made an anticyclonic loop as Typhoon Brian accelerated northwestward. On 24 October, Brian escaped to the northeast and recurved. Colleen, which had initially intensified then weakened during the period of interaction, moved westward toward Luzon. Ship reports confirmed that Colleen, with a large ragged eye, had its strongest winds in a ring displaced approximately 40 to 80 nm (75 to 150 km) from the center of the circulation.

While weakening, Colleen passed over central Luzon and then reintensified as it moved into the South China Sea. After peaking at 75 kt (39 m/sec) in the central South China Sea, at 270600Z, Colleen slowly weakened until it made landfall in central Vietnam on the morning of 28 October (Figure 3-26-4). When it was evident that the circulation was dissipating overland, the final warning was issued by JTWC at 281800Z.

### III. FORECAST PERFORMANCE

Forecasters at JTWC recognized early on that Colleen was going to be a challenge, and that's exactly how it turned out. Overall the mean track errors were significantly larger than the long term average errors with values of 130, 290 and 500 nm (240, 535 and 925 km) for the 24-, 48- and 72-hour

forecasts, respectively. In addition, JTWC tied at 24 and 48 hours with CLIPER, which is used as a baseline for determining skill, but lost to CLIPER by 10% at the 72-hour point. JTWC forecasters anticipated that interaction could occur with both Angela (24W) to the west and Brian (25W) to the east, but the question was “when, where and how much?” The forecast aids for this cyclone were in poor agreement with each other from the start. In addition, the numerical model, NOGAPS, had a difficult time resolving all three circulations and consistently tried to merge Colleen and Brian (25W). Nevertheless, once Brian (25W) escaped from its interaction with Colleen, JTWC forecasts correctly predicted that Colleen would move to the west.

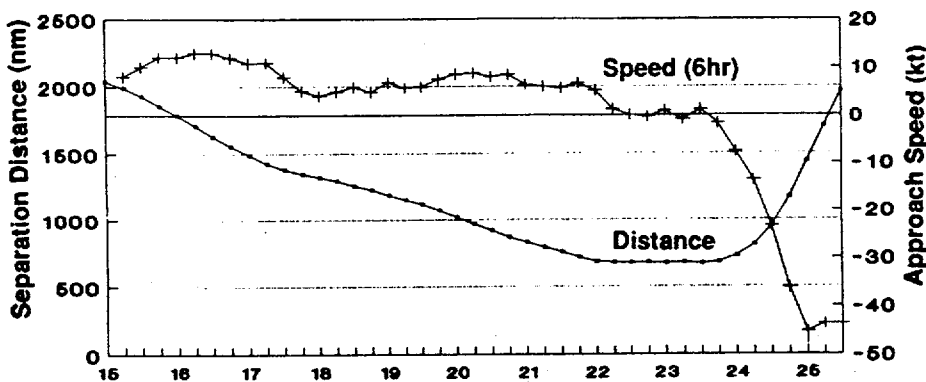


Figure 3-26-1. Graph of the relative separation distances (nm) and speeds of approach (kt) for Colleen and Brian (25W). The closest points of approach between the two typhoons occur on 22 through 24 October.

Figure 3-26-2. Graph of binary interaction between Colleen and Brian (25W). The positions, which are relative to a midpoint, show capture at 201200Z, orbit from 201200Z to 240000Z, and escape at 240000Z October.

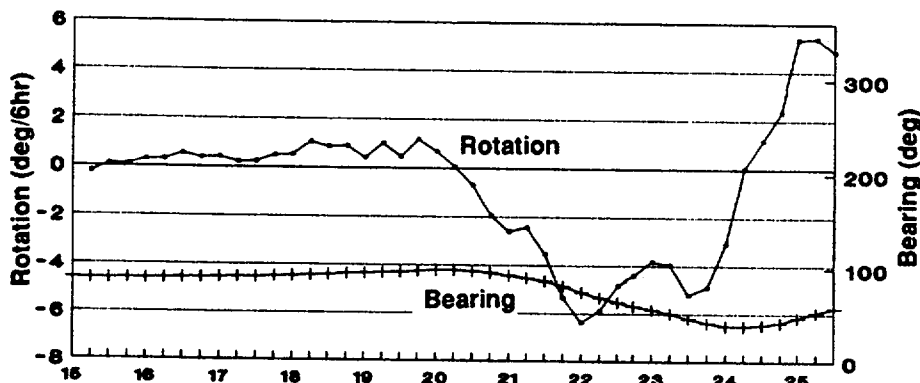
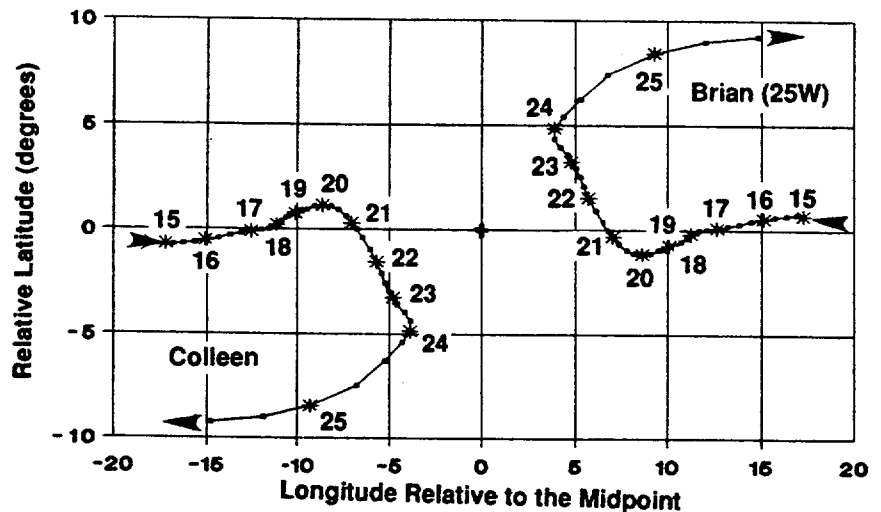
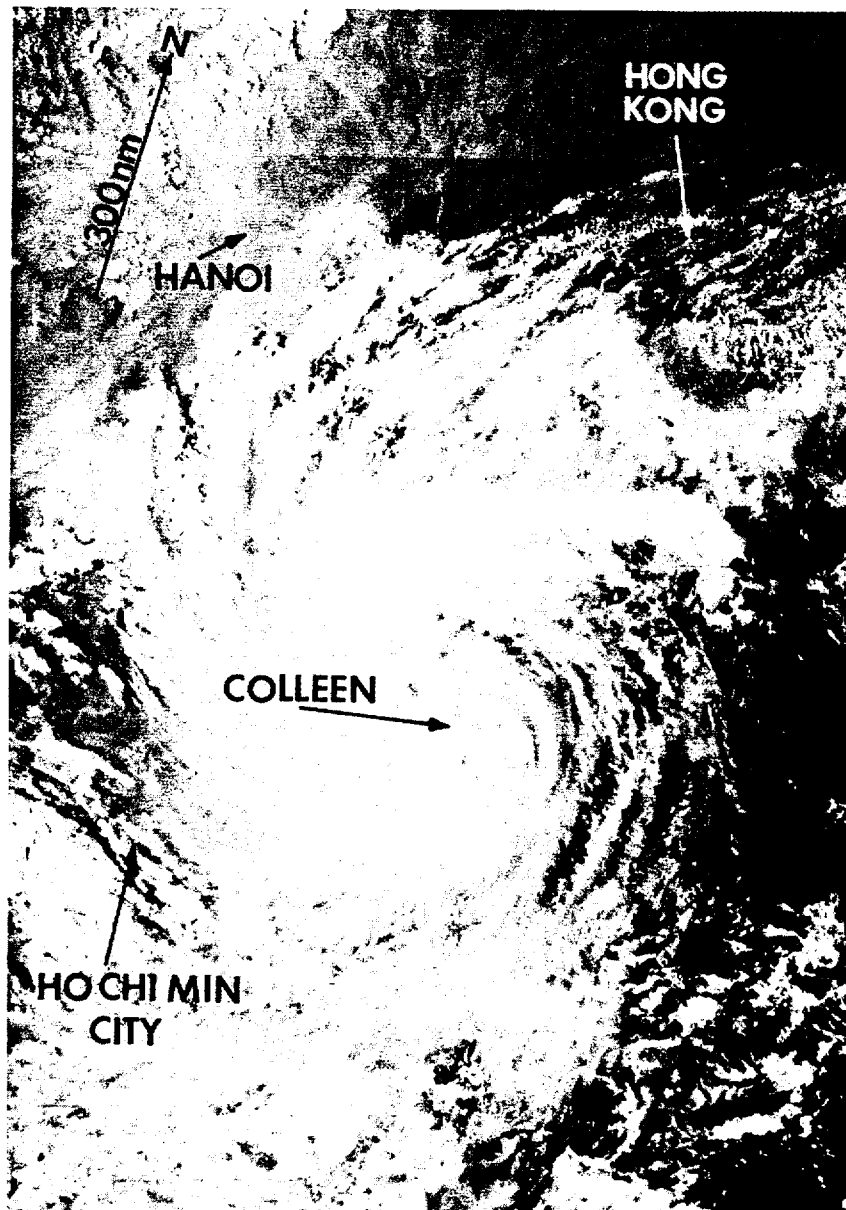


Figure 3-26-3. Graph of Colleen and Brian's rotation (degrees/6 hours) and bearing (degrees) shows that cyclonic rotation (negative values) commenced around 201200Z and ended shortly after 240000Z October.

Figure 3-26-4. Typhoon Colleen, at its peak intensity in the South China Sea, is less than a day from making landfall in Vietnam (270915Z October DMSP visual imagery).



#### IV. IMPACT

On October 21, the Korean iron ore bulk carrier, **Daeyang Honey**, was reported missing in the Philippine Sea. A nine day search effort, involving aircraft from the Navy's VQ-1 Squadron on Guam and VP-6 Squadron from Okinawa, Japan, was coordinated by the U.S. Coast Guard's Marianas Rescue Coordination Center (Guam), Japan Maritime Safety Agency, and Pan Ocean Shipping. Floating debris was ultimately found by rescue personnel, but there was no sign of the 28 crew members.

On 26 October, Colleen's torrential rains and high winds struck central Luzon. Manila experienced widespread flooding. Government offices, schools, and businesses had to close in the metropolitan area. Water was chest-high in many of the communities surrounding Manila, and over 1,300 residents had to be evacuated. One death was reported due to drowning. Farther to the north, the heavy rains triggered landslides which blocked the roads to Baguio.

No reports of fatalities or damage from Colleen's passage were received from Vietnam.

E 130 135 140 145 150 155 160 165 170 175 180 175 170 W  
N 45

**TYPHOON DAN**  
BEST TRACK TC-27W  
23 OCT - 04 NOV 92  
MAX SFC WIND 110KT  
MINIMUM SLP 933MB

**LEGEND**

- 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

130

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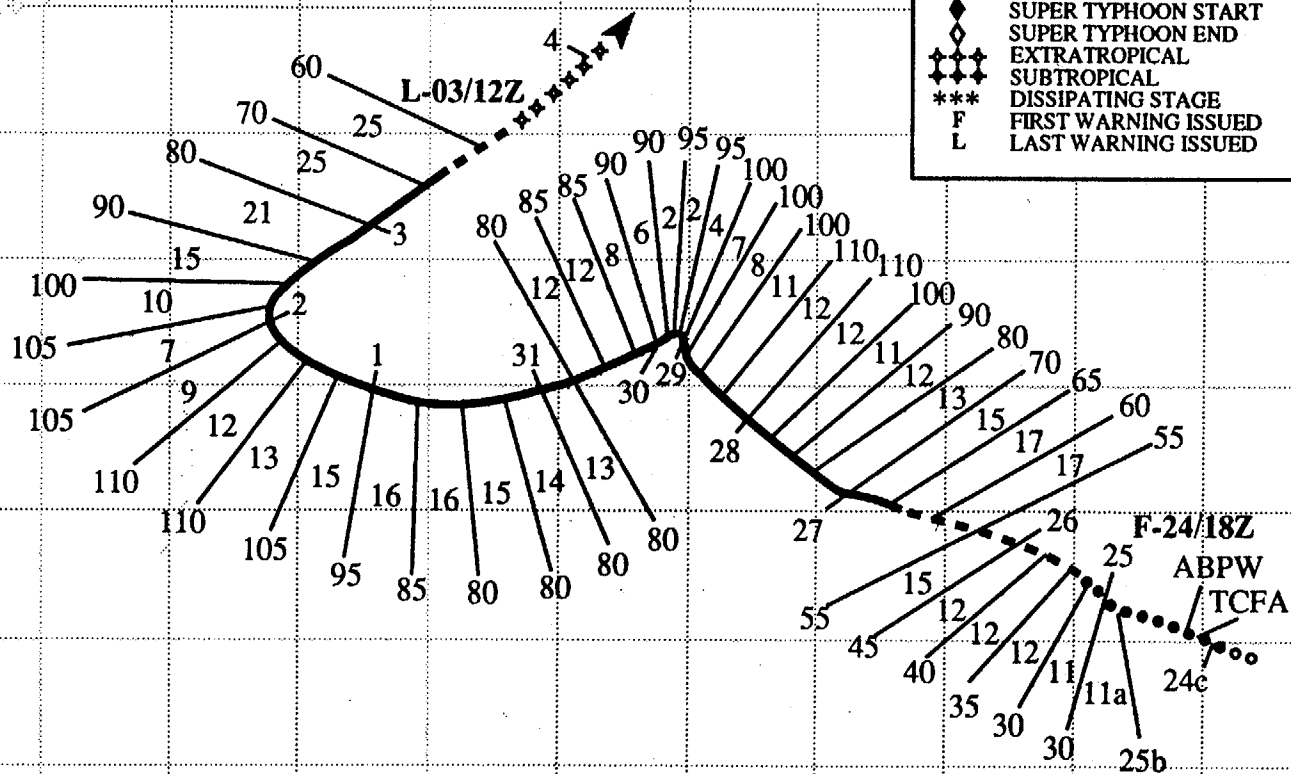
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## TYPHOON DAN (27W)

### I. HIGHLIGHTS

The last significant tropical cyclone to develop in October as part of the four storm outbreak including Angela (24W), Brian (25W) and Colleen (26W), Dan became the most destructive typhoon to strike Wake Island in the past quarter-century, causing an estimated \$9.0 million in damage. Just as Ekeka (01C) and Ward (21W) did earlier in 1992, Dan formed east of the international date line, marking the first time that three significant tropical cyclones crossed into the JTWC's area of responsibility from the central North Pacific during a single year. Later, Dan faked a move toward recurvature, took a west-southwesterly course, underwent an episode of reintensification, and finally, underwent a binary interaction with Typhoon Elsie (28W) before recurving sharply.

### II. TRACK and INTENSITY

On 23 October, the Naval Western Oceanography Center (NWOC) initially detected the tropical disturbance that developed into Dan in the trade-wind trough 450 nm (830 km) south of Johnston Island in the central North Pacific. At 240000Z, a Tropical Cyclone Formation Alert was issued by NWOC based on an increase in convection around a well-defined low-level circulation. Because of the large field-of-view geostationary images available on the MIDDAS system, satellite analysts at Detachment 1, 633 OSS (collocated with JTWC) were able to continuously monitor the ongoing development of the tropical disturbance as it tracked toward the international date line. Based on these data, which showed that the tropical disturbance was intensifying and the close proximity of the system to JTWC's area of responsibility, JTWC forecasters, in coordination with the Central Pacific Hurricane Center, elected to issue the first warning on Tropical Depression 27W at 241800Z.

As the tropical depression moved west-northwestward, normal development brought it to tropical storm intensity shortly after crossing into the western North Pacific at 251200Z. The next day, JTWC upgraded Dan to a typhoon at 261800Z. Intensification continued, and Dan began to close in on Wake Island, where it would become the most intense tropical cyclone to affect Wake since Typhoon Sarah in September, 1967. On 28 October, at the typhoon's closest point of approach (CPA) to Wake — approximately 15 nm (28 km) to the southwest — Dan had estimated maximum sustained surface winds of 110 kt (57 m/sec). The National Weather Service Office at Wake Island recorded peak wind gusts of 90 kt (46 m/sec) in the eye wall before losing electrical power (Figure 3-27-1), and a minimum sea-level pressure of 980.8 mb (Figure 3-27-2). Later reports from Wake Island indicated that the strongest winds occurred after the CPA at 280315Z.

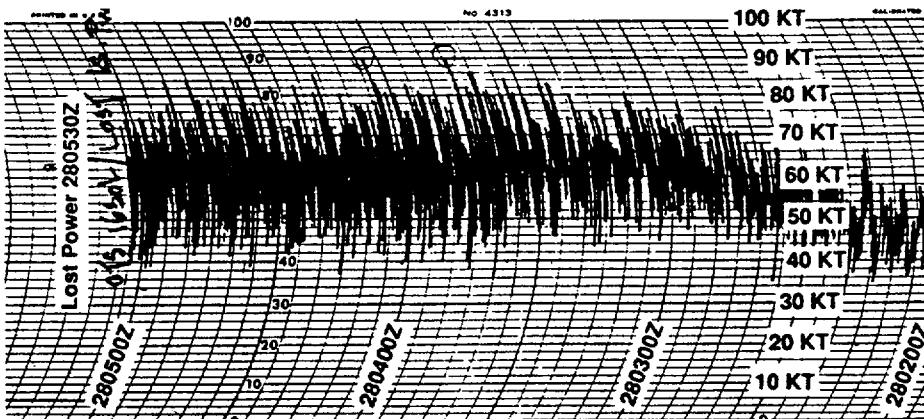


Figure 3-27-1. Wake Island's anemometer trace shows two peak wind gust to 90 kt (46 m/sec) before power was lost at 280403Z (Data courtesy of National Weather Service Office, Wake Island).

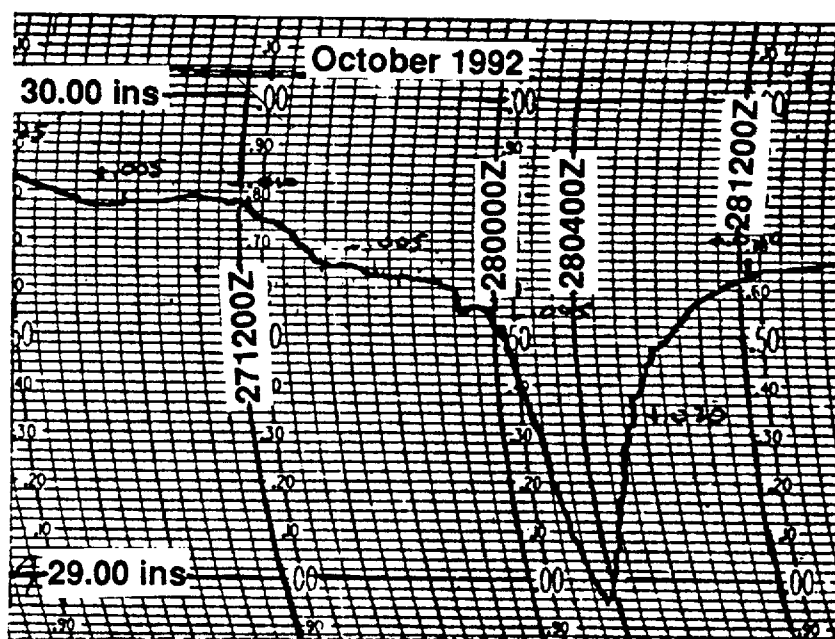


Figure 3-27-2. Microbarograph record for the period 27 through 28 October at Wake Island showing a minimum pressure of 28.95 inches (980.8 mb), at 280315Z, at Typhoon Dan's closest point of approach (Data courtesy of the National Weather Service Office, Wake Island).

On 29 October, one day after hammering Wake Island, the typhoon made a northward motion towards recurvature, stalled, and then made an abrupt track change to the west-southwest in response to the subtropical ridge strengthening after the passage of a mid-latitude trough to the north. At the same time, Dan weakened as upper-level westerlies increased aloft. As a consequence, the typhoon's eye disappeared from the satellite imagery and the typhoon's intensity dropped to 80 kt (41 m/sec). On 31 October, binary interaction commenced with Typhoon Elsie (28W), which was located to the southwest near the Mariana Islands (Figure 3-27-3).

At one point, the two cyclones closed to within 630 nm (1170 km) of each other. The upper-level shear diminished during the binary interaction event, allowing Typhoon Dan to intensify again to a peak of 110 kt (57 m/sec) at 011200Z November. Twelve hours later, Dan recurved sharply and accelerated northeastward when an approaching mid-latitude trough moving eastward from Japan created a large break in the subtropical ridge. The final warning was issued by JTWC at 031200Z, when satellite imagery indicated the system was rapidly transitioning into an extratropical cyclone.

### III. FORECAST PERFORMANCE

For JTWC, the overall mean track forecast errors were 130, 245 and 330 nm (240, 455 and 610 km) for 24, 48 and 72 hours, respectively. Although these values were larger than the long term mean, JTWC's extended outlooks for track were 30% and 60% better at 48 and 72 hours, respectively, than CLIPER. JTWC's track forecasting performance is summarized graphically in Figure 3-27-4. The four areas of concern were: the approach to Wake Island, possible recurvature after passing Wake, the effects of binary interaction with Typhoon Elsie (28W), and recurvature revisited. JTWC addressed these challenges by shifting to a northwest forecast track on 26 October, and indicated in its 260600Z Prognostic Reasoning message that the tropical cyclone would "pass near Wake Island within the next 36 to 60 hours at a peak intensity of close to 105 knots." The track and intensity forecasts made on the 26 October proved to be accurate, allowing Wake Island to make sufficient preparations two days prior to the onset of destructive winds. After Dan passed Wake Island, the forecast aids gave conflicting guidance. The climatological and statistical aids hinted at recurvature, while the numerical models and dynamic forecast aids indicated a sharp westward turn was going to occur (Figure 3-27-5). JTWC adopted a "stairstep" forecast, but at 291200Z changed its track scenario to a west-southwest track, when the track change occurred. The effects of binary interaction with Elsie (28W) on Typhoon Dan were also over-estimated by the JTWC. It was believed that the interaction would keep Dan on a nearly

westward course and preclude short-term recurvature, thus the sharpness of recurvature caught the forecasters by surprise.

On the short term, intensity forecasts were average, however, the failure of track scenario and Dan's reintensification after passing Wake Island had a definite impact on the intensity outlooks. Starting on 281200Z and for two-and-one-half days, the 72-hour intensity forecasts errors ranged from 30 to 80 kt (20 to 41 m/sec) too low, resulting in the largest intensity errors of 1992.

#### IV. IMPACT

Although the eye did not pass directly over Wake Island, Typhoon Dan devastated the tiny island which was still recovering from a near-miss by Typhoon Sybil (18W). Damage was officially estimated to be \$9.0 million. High surf surged over the surrounding coral reef, inundating most of the permanent structures. All residents sought safety in concrete shelters. For the rest of Dan's life, it threatened only maritime interests. There were no reports of any loss of life.

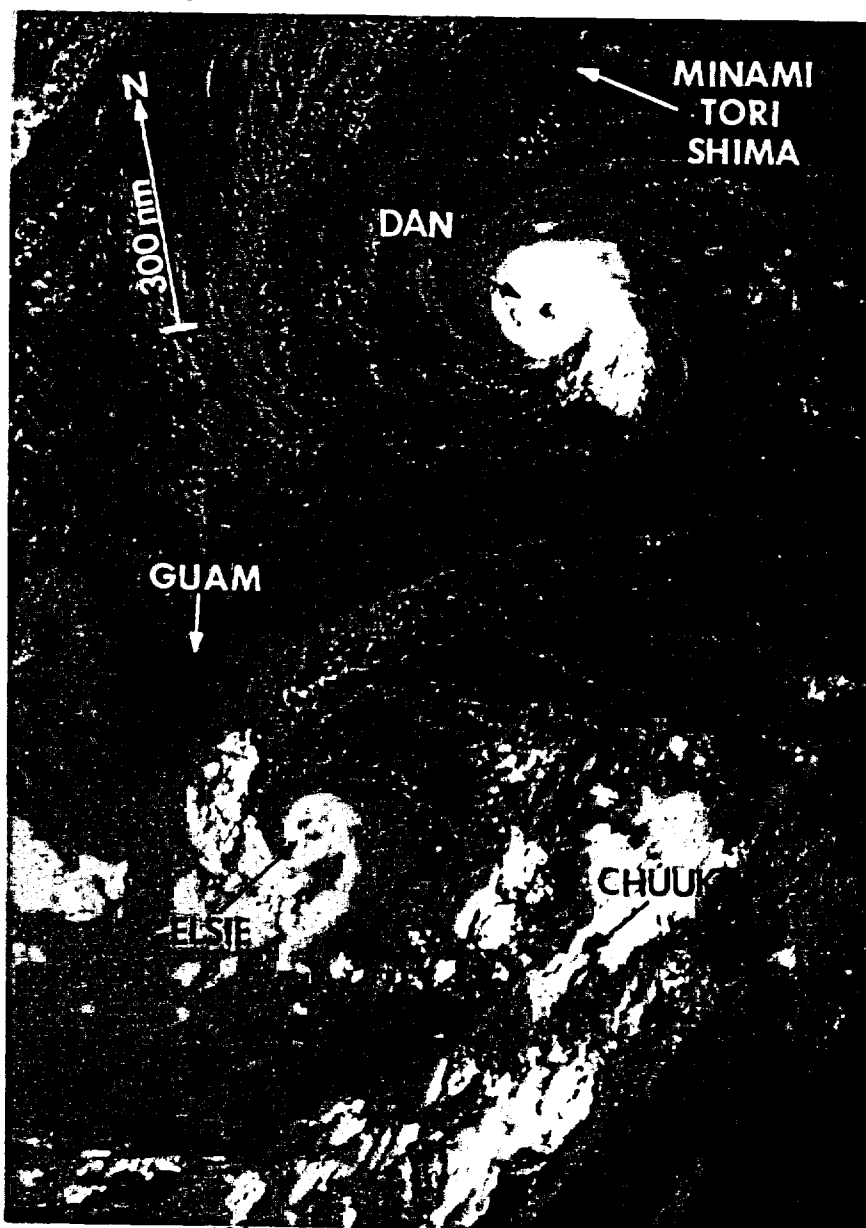


Figure 3-27-3. Near its second peak intensity, Typhoon Dan is involved in a binary interaction with Typhoon Elsie (28W), which is visible to the southwest (312258Z October DMSP visual imagery).



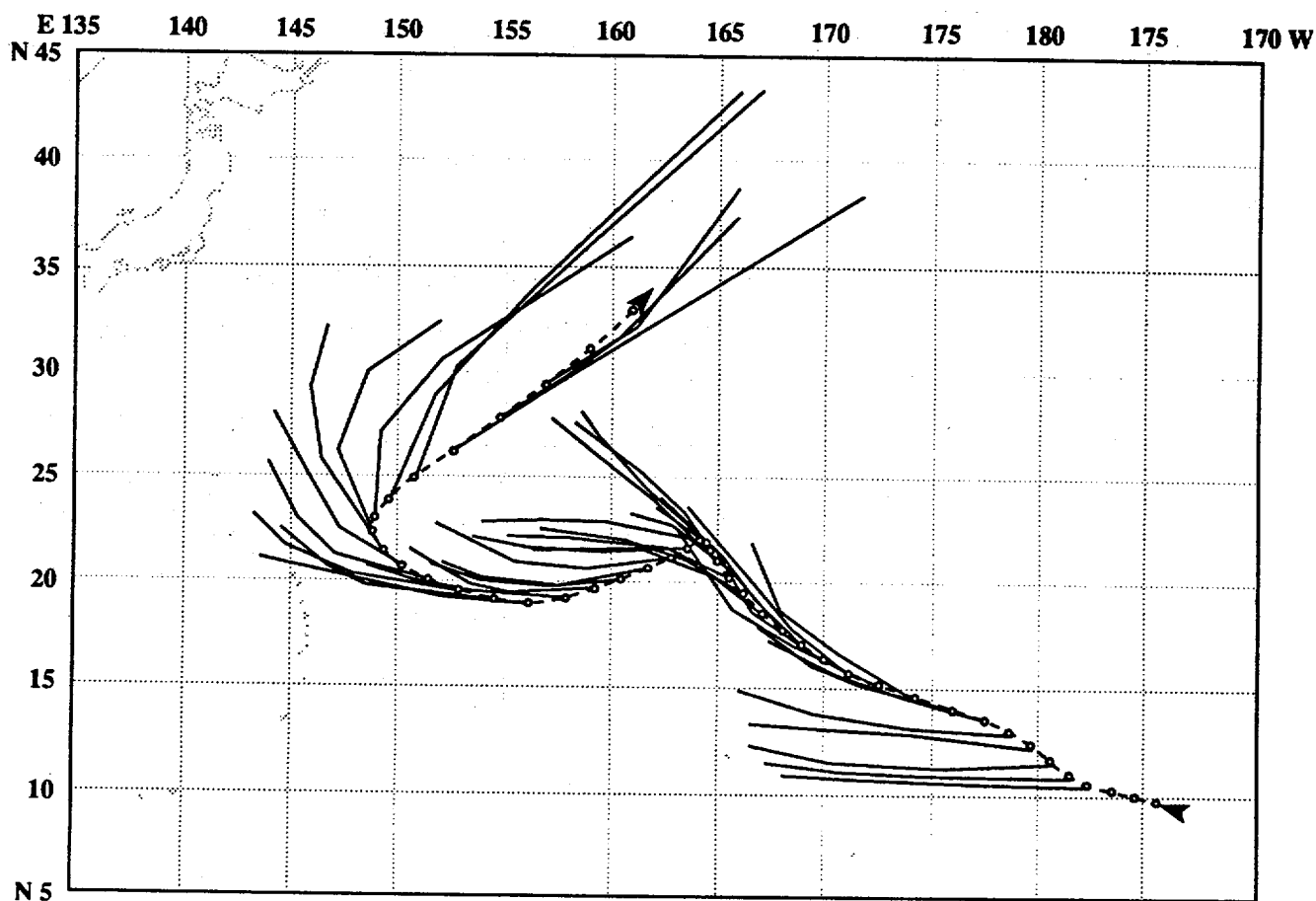


Figure 3-27-4. JTWC forecasts for Dan relative to the official best track.

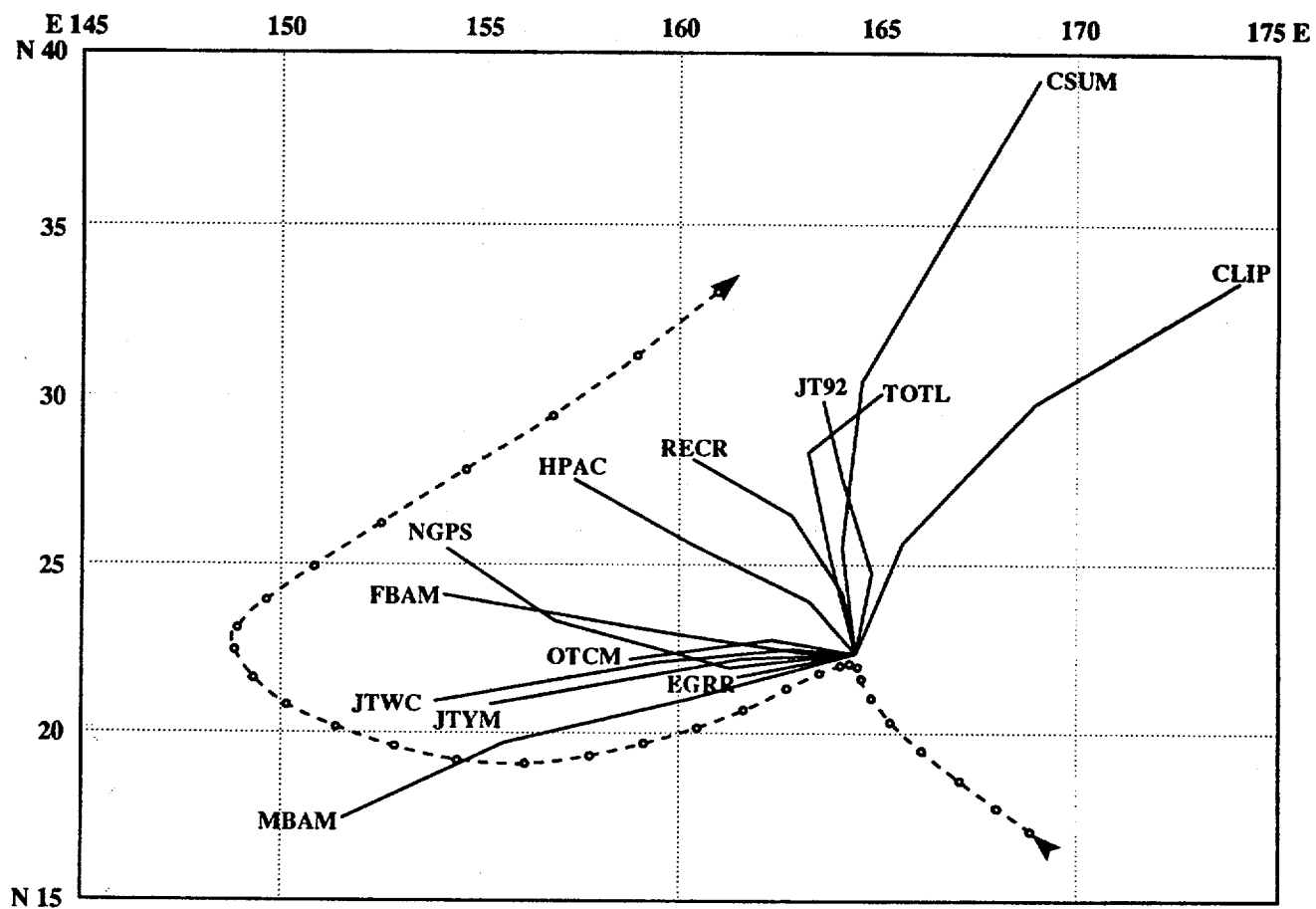


Figure 3-27-5. Forecast aids at 291200Z October for the major track change. Shown are the climatological/statistical forecast aids HPAC, CLIP, TOTL, RECR, JT92 and CSUM along with the dynamic aids OTCM, FBAM, MBAM, JTYM and the numerical models, NGPS and EGRR.

E 115 120 125 130 135 140 145 150 155 160 165 170 E  
N 45

# **SUPER TYPHOON ELSIE**

BEST TRACK TC-28W  
27 OCT - 09 NOV 92  
MAX SFC WIND 145KT  
MINIMUM SLP 892MB

40

35

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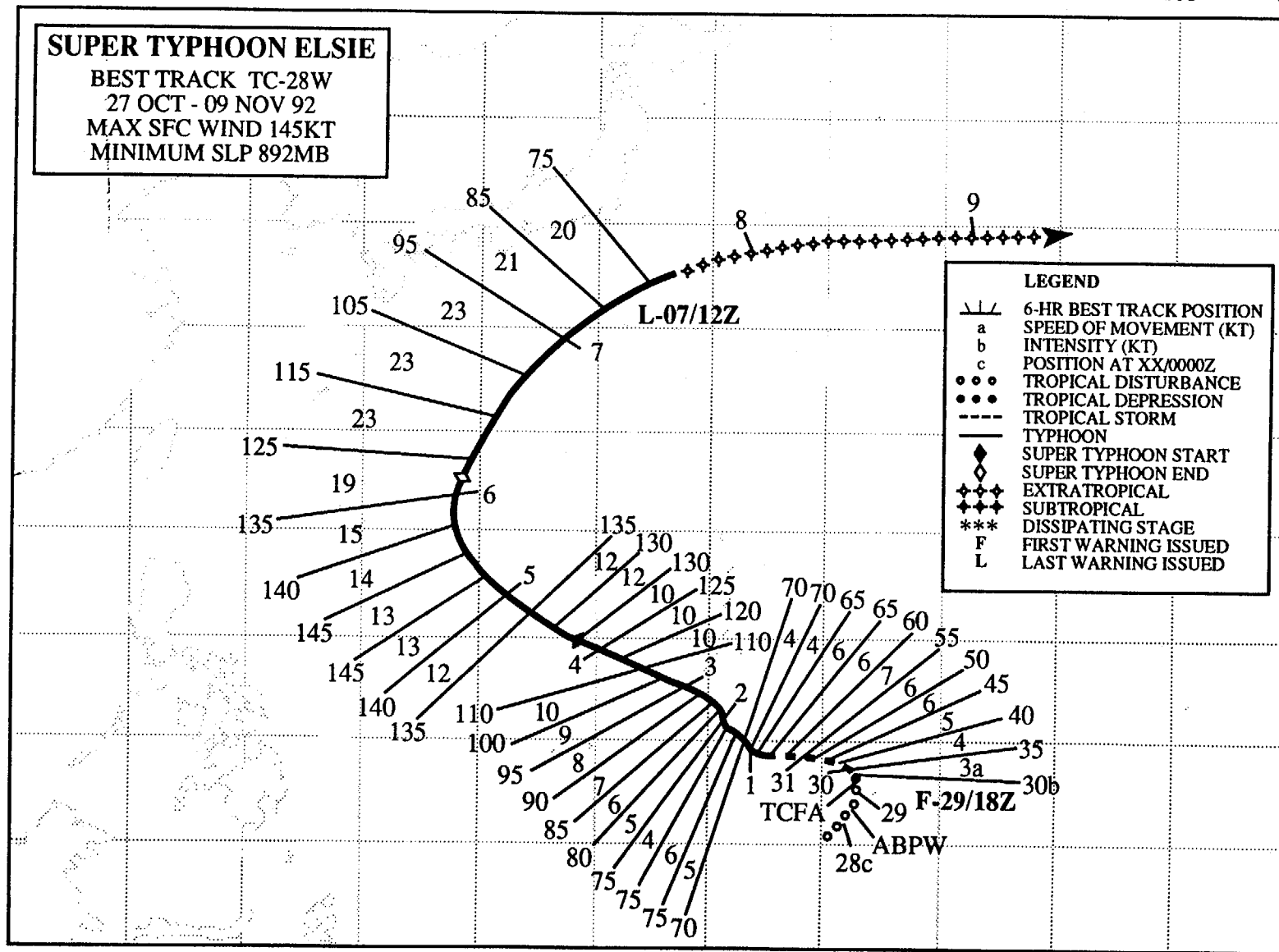
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## **SUPER TYPHOON ELSIE (28W)**

### **I. HIGHLIGHTS**

The fourth super typhoon of 1992, Elsie was the third typhoon to pass within 60 nm (100 km) of Guam in less than three months. After initial movement to the northeast in response to a southwest monsoonal surge, a subsequent turn to the west, and then interaction with Typhoon Dan (27W), Elsie settled down on a track to the northwest, recurved, and transitioned into a hurricane-force extratropical low.

### **II. TRACK AND INTENSITY**

The tropical disturbance that became Elsie formed in the monsoon trough near Chuuk in the central Caroline Islands, and was first described on the 280600Z October Significant Tropical Weather Advisory as an area of poorly organized, persistent convection. The combination of increasing deep convection near the cloud system center and falling pressure in excess of 3 mb in 24 hours at Chuuk (WMO 91344) led forecasters at JTWC to issue a Tropical Cyclone Formation Alert at 291200Z. A short time later, the appearance of deep cyclonically curved spiral convective bands around the system center prompted JTWC to issue the first warning for Tropical Depression 28W at 291800Z.

The tropical cyclone initially moved to the northeast in response to a deep southwest monsoonal surge. The northward component of this movement, plus the depression's early intensification, brought the tropical cyclone under the influence of the mid-level steering flow of the subtropical ridge to the north, causing the track to become more westward. As intensification continued at a rate of 1.25 mb/hour, JTWC upgraded Elsie to a tropical storm six hours later on the 300000Z warning, and to a typhoon at 301200Z. Meanwhile, the separation distance between Elsie and Typhoon Dan (27W) was steadily decreasing. During the period 311800Z October through 020600Z November, binary interaction between the two typhoons caused Elsie to slow, undergo erratic motion, and again take a more northward track toward the southern Mariana Islands. At the same time, the outflow from Dan (27W) was causing moderate upper-level shear from the east across Elsie's cloud shield, and retarding intensification. At its closest point of approach to Guam on 2 November, Elsie was located 55 nm (100 km) to the south-southwest of the island. Peak wind gusts to 62 kt (32 m/sec) were recorded at the Naval Air Station, Guam (WMO 91212), but recordings were not available for the southern portion of the island.

After Dan (27W) recurved, ending the binary interaction on 2 November, Elsie resumed development at a rate of 5 kt (3 m/sec) per six hours, reaching super typhoon intensity at 040600Z and a peak of 145 kt (75 m/sec) at 050600Z (Figure 3-28-1). Elsie's intensification kept Guam in gale-force winds for two days after its passage and movement away from the southern Mariana Islands. After Elsie's recurvature at 060000Z, increasing southwesterly winds aloft weakened the super typhoon to typhoon intensity at 060600Z. As Elsie was transitioning into an intense extratropical low with hurricane-force winds, the final warning was issued by JTWC at 071200Z.

### **III. FORECAST PERFORMANCE**

Although Elsie's track is basically one of recurvature, the initial monsoon surge from the southwest, binary interaction, recurvature and the subsequent acceleration into midlatitudes proved difficult to handle. With mean track errors of 110, 250 and 340 nm (205, 465 and 630 km) for the 24-, 48- and 72-hour forecasts, respectively, JTWC's performance overall was below average and tied with CLIPER. The specific forecasting successes were accurately predicting Typhoon Dan's (27W) influ-

ence on Elsie's track change to the north and anticipating Elsie's intensification to a super typhoon. With respect to Guam, JTWG predicted that intensification would take place a little early and that the typhoon would pass 30 nm (55 km) closer than actually occurred. For Okinawa, JTWG forecasts were used to prevent the unnecessary preparations for destructive winds at DOD installations there.

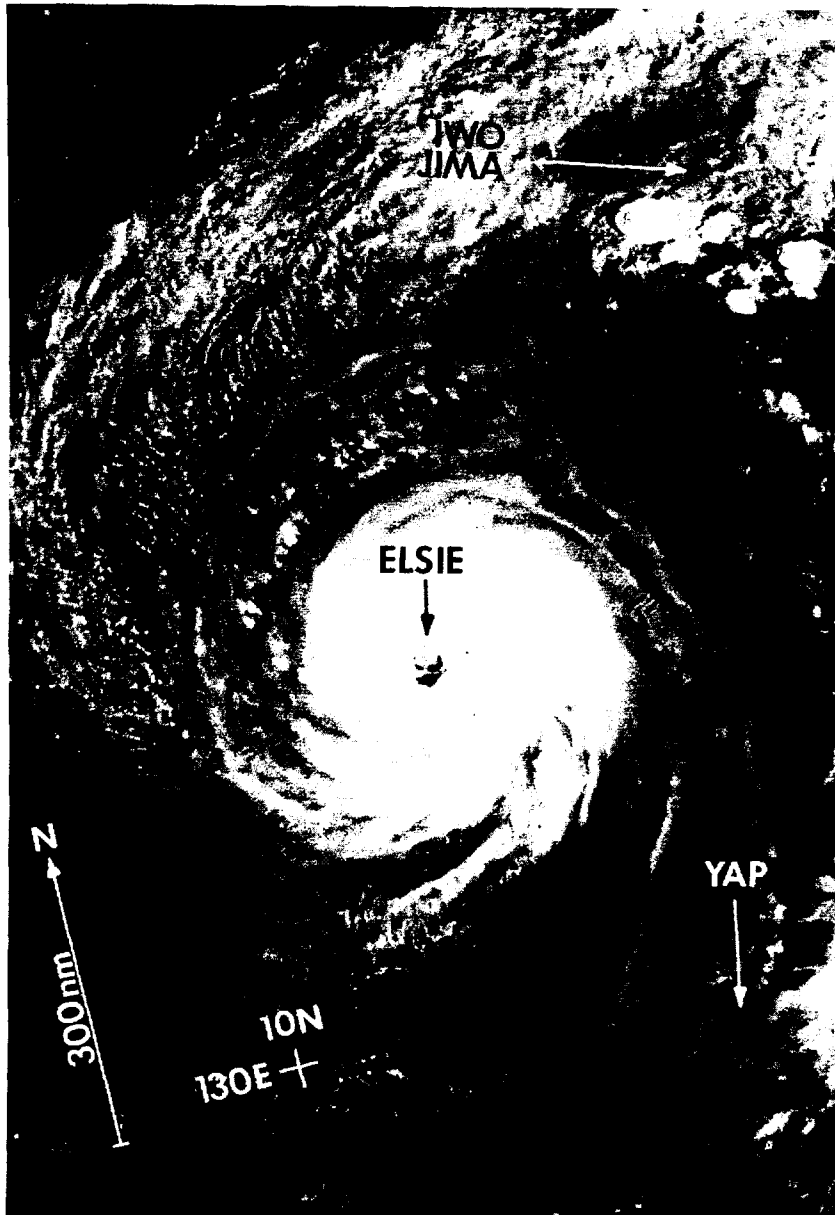
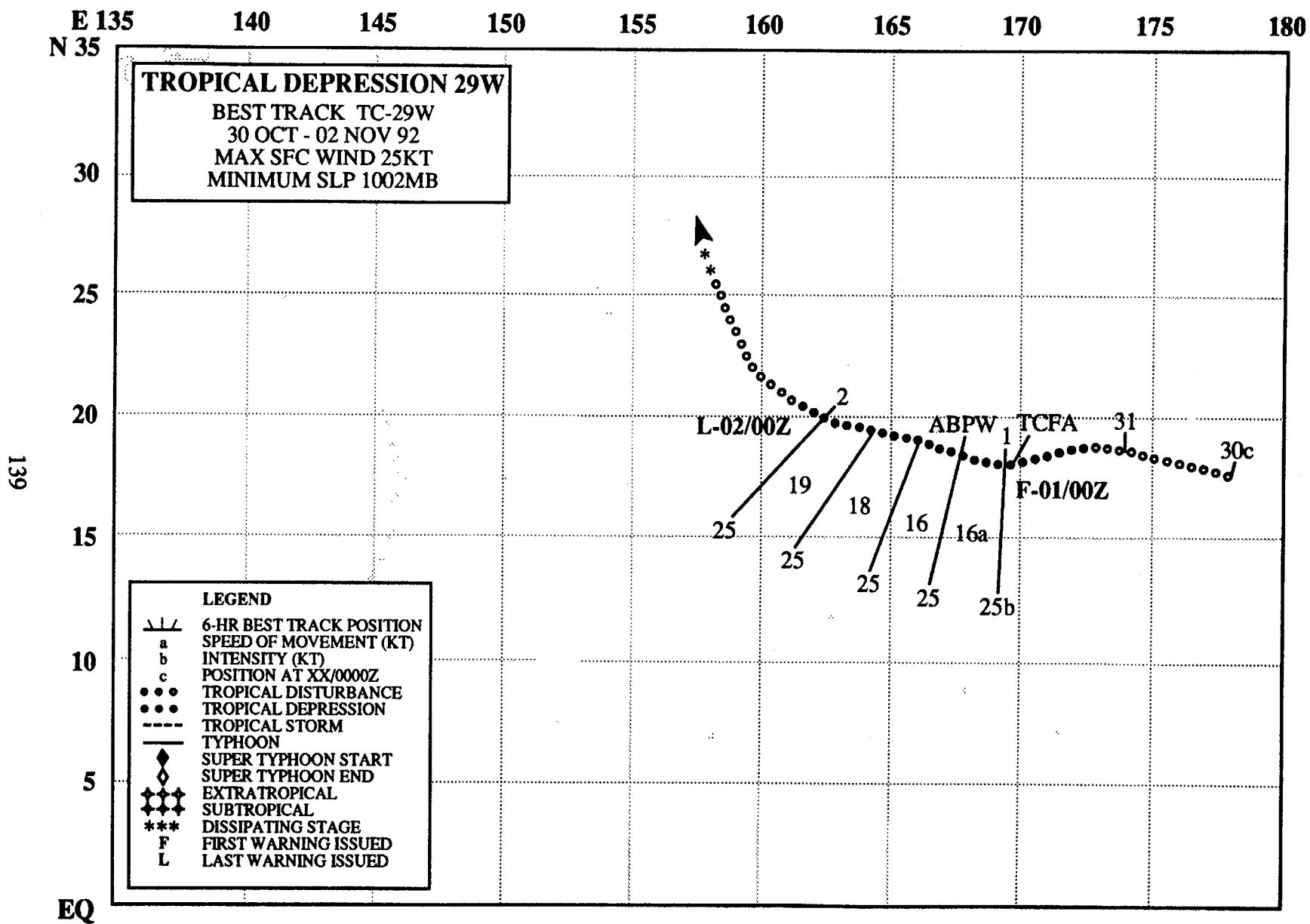


Figure 3-28-1. Elsie at super typhoon intensity in the central Philippine Sea (042342Z November DMSP visual imagery).

#### IV. IMPACT

On Guam, no deaths, injuries, or significant property damage occurred. As a precaution, military aircraft from the Navy's VQ-1, VQ-5 and VRC-50 squadrons were temporarily relocated from Guam to Japan, and all ships in port at Guam were sent to sea. Residents of Guam and Rota spent a day in typhoon Condition of Readiness 1, and the Guam general election had to be postponed for the first time in its history.

Later on, as Elsie moved northward in the Philippine Sea, the repositioning of some support units for the military exercise, ANNUAL-EX 92, had to be delayed.



## TROPICAL DEPRESSION 29W

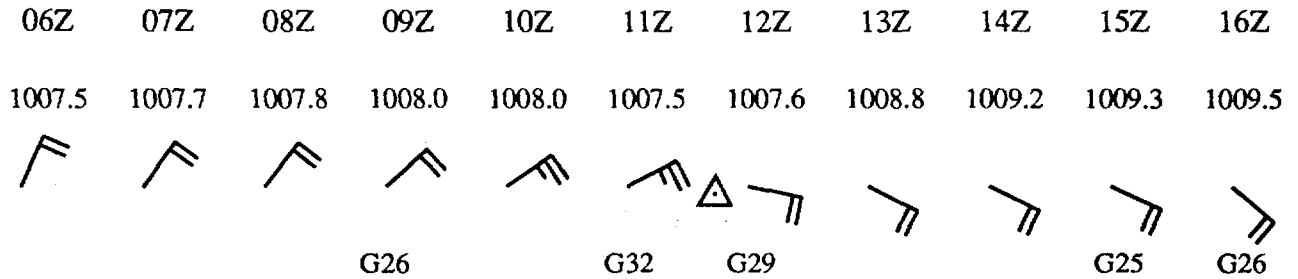
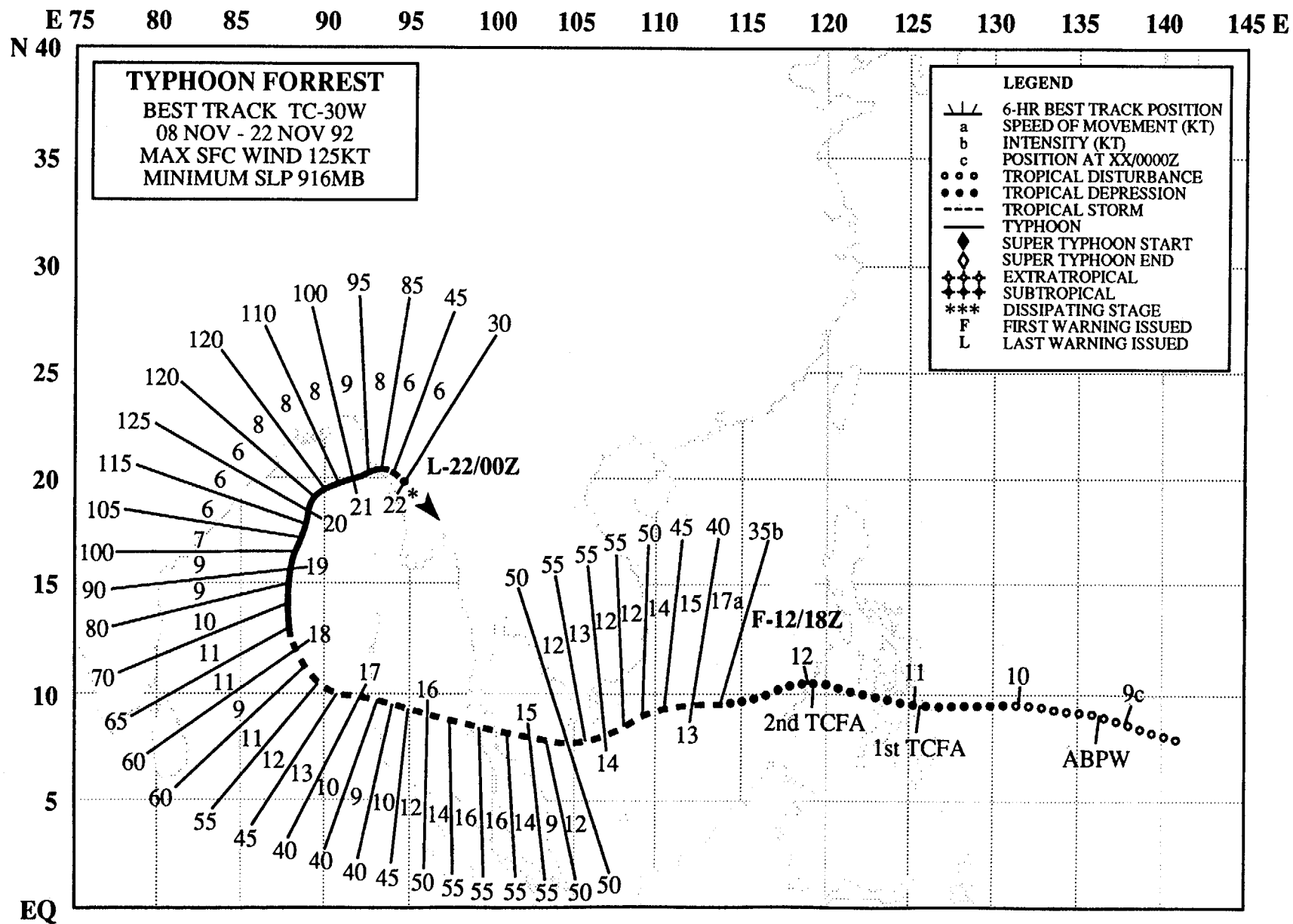


Figure 3-29-1. Surface reports from Wake Island (WMO 91245) for the period 010600Z through 011600Z November reflect the passage of Tropical Depression 29W at 011100Z with the winds shifting from the northeast to the southeast.

Forming in the wake of Typhoon Dan (27W), Tropical Depression 29W immediately become a threat to Wake Island which had already been heavily damaged by Dan (27W) on 28 October. Fortunately for Wake, the Tropical Depression's intensification was severely curtailed by the persistent outflow from Dan (27W). When Tropical Depression 29W reached its closest point of approach, 30 nm (55 km) to the south-southwest of Wake, at 011200Z, the island experienced surface winds gusting to 32 kt (16 m/sec).





## **TYPHOON FORREST (30W)**

### **I. HIGHLIGHTS**

The second of four significant tropical cyclones to start in November, Forrest became part of a three storm outbreak with Gay (31W) and Hunt (32W). Forrest was the only tropical cyclone of 1992 to track from the western North Pacific, across the South China Sea, and into the Bay of Bengal. It reached a maximum intensity of 125 kt (64 m/sec) in the Bay of Bengal over a day after it had started recurvature.

### **II. TRACK AND INTENSITY**

On 9 November, the tropical disturbance that became Forrest was detected as a persistent area of convection in the western Caroline Islands, and was first mentioned on the 090600Z Significant Tropical Weather Advisory. As the tropical disturbance was approaching the southern Philippine Islands, an increase in its convective organization prompted JTWC to issue a Tropical Cyclone Formation Alert on 102300Z, forecasting for further development once the disturbance exited the Islands. The cloud system was slow to intensify and required the alert to be reissued at 112300Z. Once past Palawan Island and over open water in the South China Sea, the disturbance's organization and convection increased rapidly. JTWC issued the first warning on Tropical Depression 30W at 121800Z. The upgrade to Tropical Storm Forrest followed at 130000Z, which in post analysis appeared to be six hours slow.

As Forrest continued westward, disruptive land interactions with southern Vietnam and the Malay Peninsula temporarily prevented it from developing into a typhoon. On 15 November, the tropical storm crossed the Malay Peninsula and lost most of its central convection (Figure 3-30-1). Although a low-level circulation center remained, Forrest continued to slowly weaken for the next two days. Its central convection rebuilt and again became persistent on 17 November. Coincident with the tropical storm's intensification came a gradual track change to the north in response to the steering provided by the subtropical ridge over Southeastern Asia. At 180600Z, Forrest reached typhoon intensity and passed through the axis of the mid-tropospheric subtropical ridge to begin its recurvature. Despite the recurvature, upper-level winds were from the south-southwest, and provided enhanced outflow. As a result, Forrest reached its peak intensity of 125 kt (64 m/sec) 36 hours after it commenced recurvature. As Forrest proceeded to the north, sharper recurvature commenced, and increasing upper-level wind shear from the southwest started to weaken the typhoon. On 21 November, Forrest underwent rapid weakening as it made landfall on the coast of Burma. At landfall, the maximum surface winds gusting to 56 kt (29 m/sec) were recorded at Cox's Bazar (WMO 41992), Bangladesh, 75 nm (140 km) north of the cyclone's center. Based on Forrest's rapid dissipation over Burma's rugged terrain the final warning was issued by JTWC at 220000Z (Figure 3-30-2).

### **III. FORECAST PERFORMANCE**

The sample of mean track forecast errors for the South China Sea area was small and the errors of 75 and 105 nm (135 and 195 km) for 24 and 48 hours, respectively, were roughly equal to CLIPER. The mean forecasting errors for track in the Bay of Bengal were considerably larger at 100, 220 and 415 nm (185, 405 and 770 km) for 24, 48 and 72 hours, respectively. This performance, which again matched CLIPER's performance, was average for the short range, and less than average for the extended outlooks. JTWC did correctly forecast Forrest's track change to the north in the Bay of Bengal, but did

not anticipate the sharpness of the typhoon's turn towards the coast of Burma three days later.

The intensity forecasts were good, except for a two-and-one-half-day period starting on 160600Z where the 72-hour extended outlooks were 35 to 80 kt (18 to 41 m/sec) too low when forecast weakening in the central Bay of Bengal did not occur, and unforecast intensification did occur.

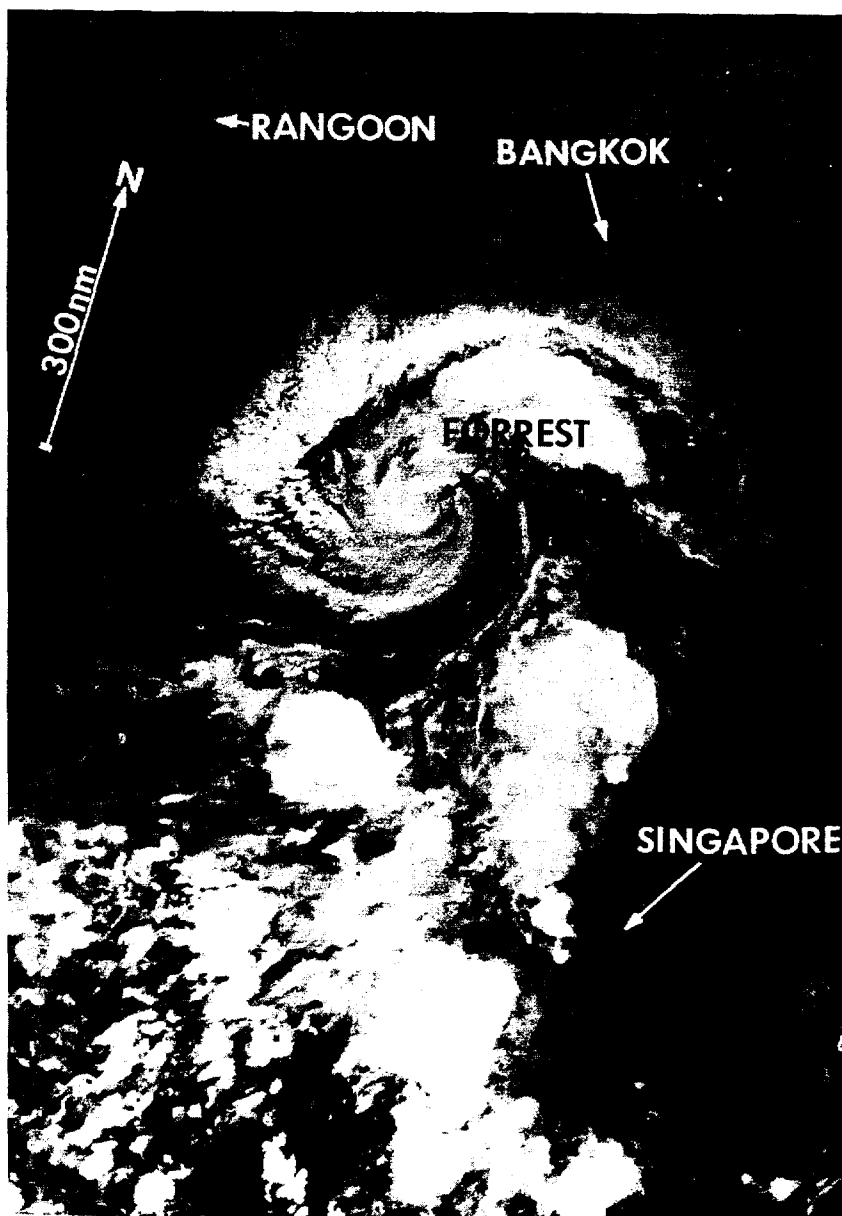


Figure 3-30-1. Forrest's cloud pattern remains tightly coiled as the tropical cyclone crosses the Malay Peninsula (151419Z November DMSP infrared imagery).

#### IV. IMPACT

In the Gulf of Thailand, Forrest threatened the numerous manned gas platforms. All platforms were evacuated in advance of the tropical storm's approach and no injuries were reported. Afterward, Forrest swept across the Malay Peninsula. No fatalities were reported, most probably due to the evacuation of approximately 10,000 people from the coastal areas. More than 1000 houses and many roads were seriously damaged or destroyed.

As the typhoon turned in the direction of the northern Bay of Bengal, authorities in the region had not forgotten the effect of Tropical Cyclone 02B, which struck Bangladesh in April 1991 killing an estimated 138,000 people. Disaster preparedness officials in Bangladesh successfully evacuated of an estimated 500,000 people in response. Fortunately, the center of Forrest went ashore in a relatively sparsely populated region of Burma and spared Cox's Bazar where over 250,000 Burmese refugees were housed in tents. U.S. agencies had activated plans for a massive relief effort, but the sharper recurvature and small size of Forrest allowed the plans to be canceled. Only two fatalities in Bangladesh were reported.

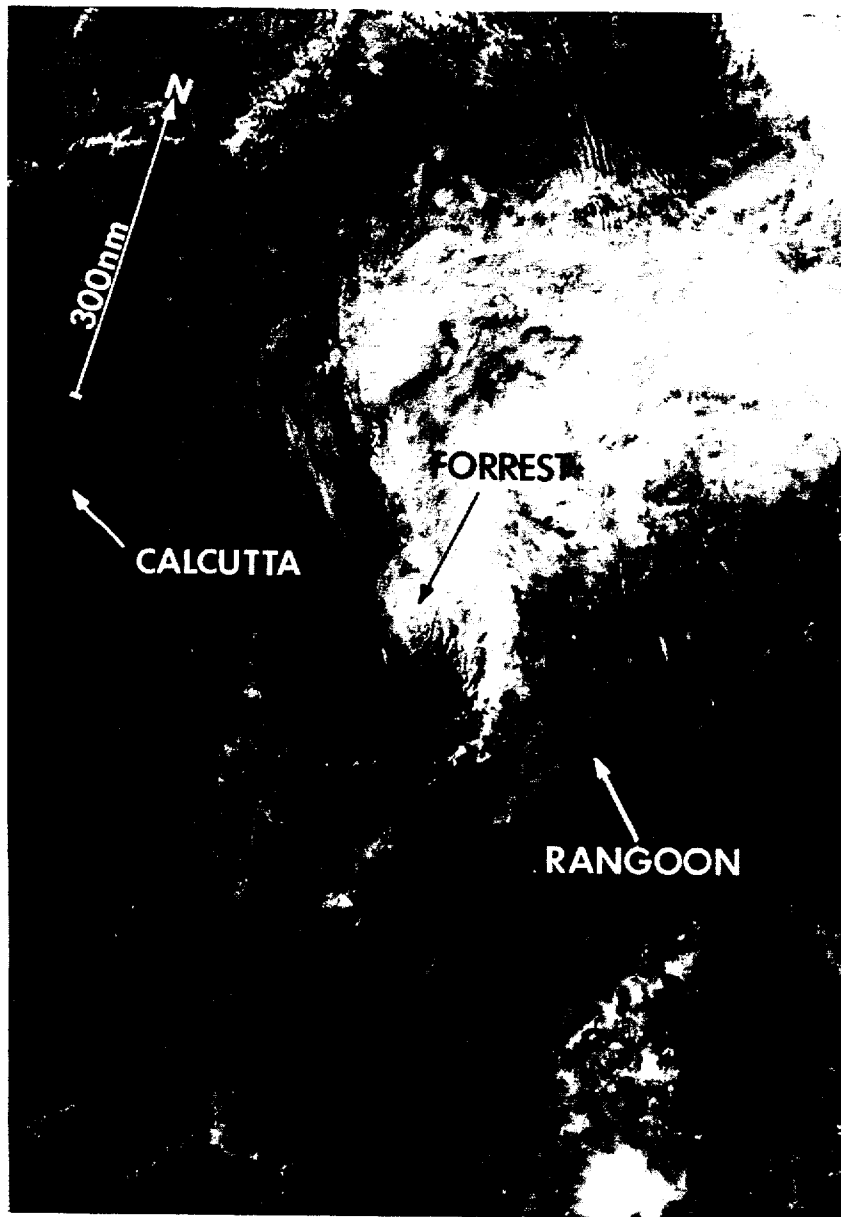
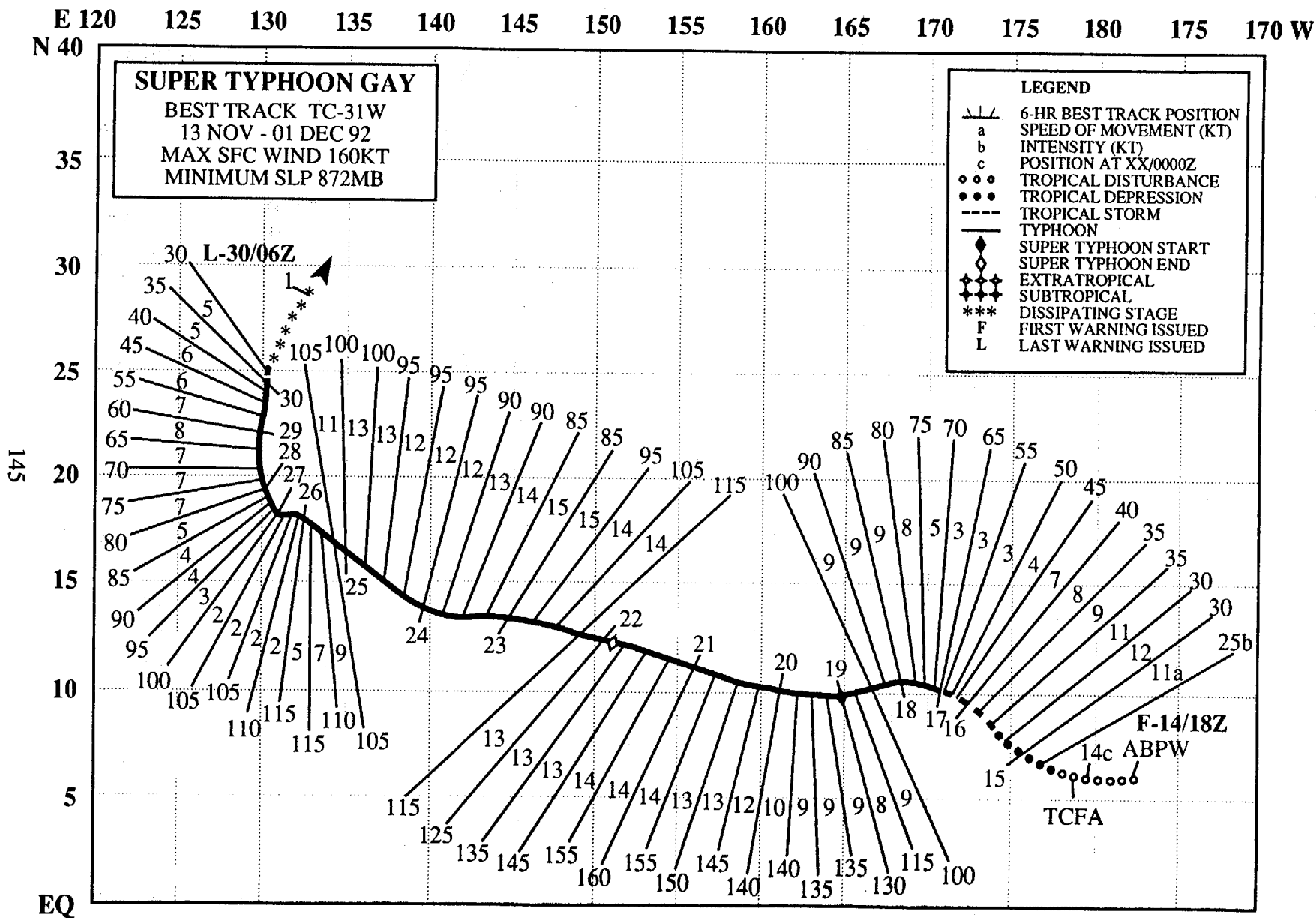


Figure 3-30-2. After being overland for 12 hours, all that remains of Forrest is a low-level cloud vortex (220255Z November DMSP visual imagery).



## **SUPER TYPHOON GAY (31W)**

### **I. HIGHLIGHTS**

Gay was noteworthy for five reasons: its eye became the record third to pass across Guam in less than three months; it was estimated to be the most intense tropical cyclone to occur in the western North Pacific since Super Typhoon Tip in October of 1979; it went through two intensification periods, which is not rare but is relatively uncommon; it filled an estimated 99 mb in less than 48 hours without moving over land; and, it required the highest number of warnings, 63, for any western North Pacific tropical cyclone in 1992. Four days after being detected as a tropical disturbance, Gay slammed into several of the Marshall Islands with typhoon force winds. After peaking with sustained winds of 160 kt (82 m/sec) with gusts to 195 kt (100 m/sec), the super typhoon weakened for two days before reaching Guam. Typhoon Gay passed across the center of Guam on 23 November, then reintensified to a second peak before recurving, and dissipating over water south of Japan.

### **II. TRACK AND INTENSITY**

On 13 November, the tropical disturbance that became Super Typhoon Gay was detected just east of the international date line in the monsoon trough which extended westward through the southern Marshall Islands, where Hunt (32W) was forming, to Tropical Storm Forrest (30W) in the South China Sea. JTWC first mentioned the disturbance as a convective area with fair potential for development on the 130600Z November Significant Tropical Weather Advisory. As the disturbance moved westward, the overall area of cloudiness decreased, but there was a marked increase in central convection and organization. To address this development, the Center issued a Tropical Cyclone Formation Alert at 140500Z. Intensification continued and the first warning followed at 141800Z with an upgrade to Tropical Storm Gay at 150000Z.

As Gay approached the Marshall Islands and slowed, it intensified reaching typhoon intensity at 170000Z. Mejit Island and the atolls of Ailuk and Wotje, just east-northeast of Kwajalein Atoll, were the first to be buffeted by the typhoon which inflicted considerable damage. Then Typhoon Gay swept westward, passing 60 nm (110 km) north of Kwajalein, and later over Wotho Atoll, where all the homes and crops were destroyed, fortunately without any loss of life. At 190600Z, JTWC upgraded Gay to a super typhoon, the peak intensity of 160 kt (82 m/sec) based on estimates from satellite imagery was not reached until 210000Z. This peak intensity, although estimated, established Gay as the most intense typhoon to occur in the western North Pacific since Typhoon Tip peaked in October 1979 with sustained winds of 165 kt (85 m/sec).

In the meantime, Typhoon Hunt (32W) had brushed by Guam, intensified, recurved, and was located, on 21 November, on the north side of the subtropical ridge, north of Guam, and north-northwest of Super Typhoon Gay. From this position, Hunt's strong upper-level outflow combined with a massive upper-level anticyclone to the north-northeast of Gay brought strong northeasterly flow to bear on Gay, decapitating the north side of its well organized thunderstorm structure. As a consequence, sea-level pressures began to rapidly rise within the typhoon's eye, the torrential rains abated, and the winds within the core region spun down faster than forecast by JTWC.

Fortunately, for the southern Mariana Islands, the weakening trend continued at a phenomenal rate of 10 kt (5 m/sec) per 6 hours, and JTWC downgraded the super typhoon to typhoon status at 221200Z. Twelve hours later, Gay crossed Guam (Figure 3-31-1) packing sustained winds of 85 kt (44 m/sec) gusting to 105 kt (54 m/sec). Post analysis indicates that during the rapid weakening event,

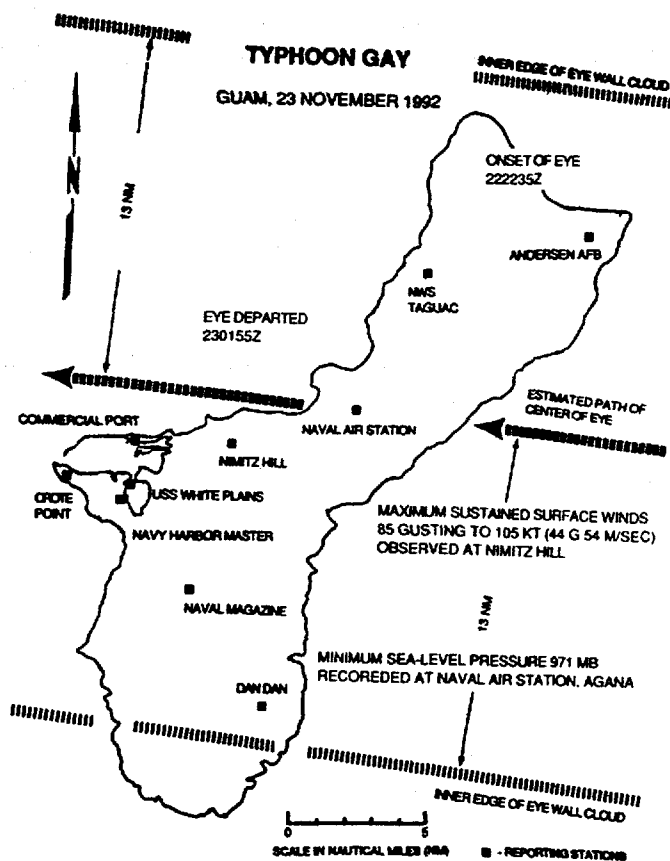


Figure 3-31-1. Graphic depicting the passage of the eye of Typhoon Gay across the island of Guam on 23 November.

JTWC's intensity estimates lagged the actual intensities by about 12 hours. The eye passage at Nimitz Hill is graphically shown on the pressure trace in Figure 3-31-2. The minimum sea-level pressure of 971 mb was recorded at the Naval Air Station. In Figure 3-31-3, the Nimitz Hill wind speed and direction record shows the light winds during the eye passage and that the wind direction gradually shifted in a clockwise direction. The wind record also shows that before the eye passed, the north-northwest winds were more uniform or stable, while in contrast, after the eye passed, the flow across Nimitz Hill was southerly, more turbulent and stronger. In terms of strength and size, Gay was large, nearly 800 nm (1480 km) across. As a result, the winds at Andersen AFB (WMO 91218), Guam gusted to gale force (33 kt (17 m/sec)), or higher, for 24 hours. Even with the duration and strength of these winds, the structural damage on Guam and Rota was relatively light. Damage would have been much greater, probably in the tens of millions of dollars, had Typhoon Omar (15W) not hit Guam less than three months earlier and destroyed the weaker structures. Nevertheless, due to surprisingly light 24-hour rainfall amounts from 1.5 to 3.5 inches (40 to 90 mm), the winds of this "dry" typhoon were laden with salt and left the island's new growth of vegetation and crops as if scorched or seared from intense heat. The maximum storm surge and wave runup were generally from 5 to 7 feet (2 m) on northern exposed reefs and beaches with a maximum near the Cabras port/container area of 9 to 11 feet (3 m) (Figure 3-31-4).

On 23 November, the effect of Hunt's (32W) outflow on Gay lessened. The environment allowed the deep thunderstorm structure to redevelop, and Typhoon Gay reintensified, reaching a second peak of 115 kt (59 m/sec) at 251800Z (Figure 3-31-5). The typhoon stalled for two days and weakened south-southeast of Okinawa, Japan before tracking to the north on 27 November. As Gay recurved

Figure 3-31-2. The microbarograph trace for Nimitz Hill, Guam shows the passage of Typhoon Gay's center on 23 November. The instrument, which was corrected to sea level, recorded a minimum pressure of 972 mb.

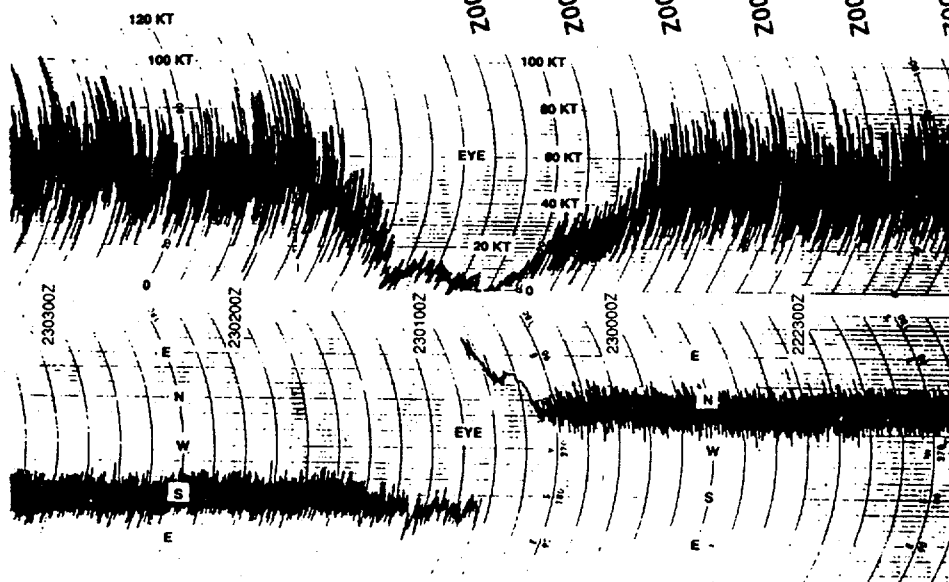
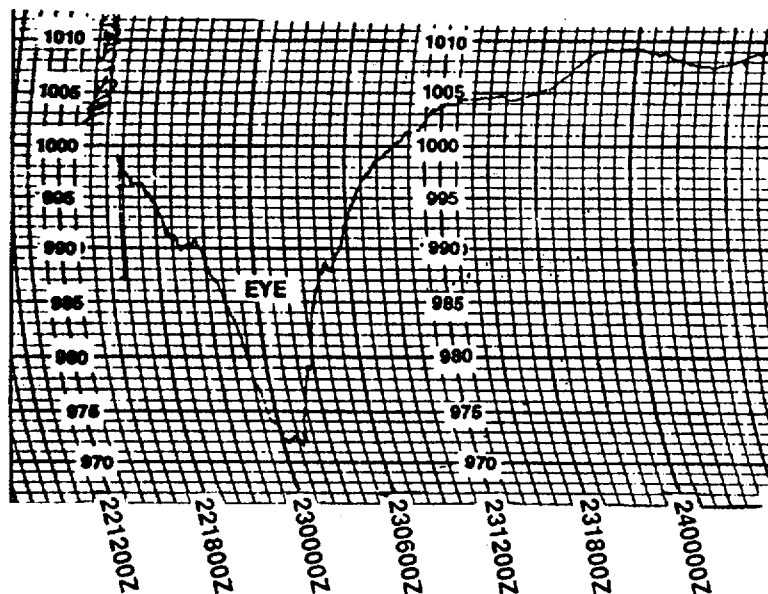


Figure 3-31-3. The passage of the eye of Typhoon Gay as measured by the anemometer at Nimitz Hill, Guam on 23 November.

southeast of Okinawa on 30 November, JTWC downgraded the typhoon to a tropical storm. The following day, the last of 63 warnings, the most for any 1992 tropical cyclone, was issued at 300600Z as the system dissipated over water south of Japan.

### III. FORECAST PERFORMANCE

The overall mean track forecasting errors were 85, 155 and 200 nm (155, 285 and 370 km) for 24, 48 and 72 hours, respectively. JTWC's performance was 60-70% better than average, and provided an overall 70, 60 and 55% improvement over CLIPER for the 24-, 48- and 72-hour forecasts, respectively. JTWC got a head start on the aids on the very first warning by correctly anticipating Gay's track toward Guam. While JTWC had a fairly good handle on the tropical cyclone's motion, the dynamic guidance consistently recurved Gay well east of Guam. The numerical model guidance provided by NOGAPS actually got worse as the typhoon approached Guam, even depicting movement to the north as Gay passed directly overhead. NOGAPS predicted that Typhoon Hunt (32W) would stall east of Guam and that Gay would take a more northerly course, recurving prior to Hunt. OTCM, FBAM,

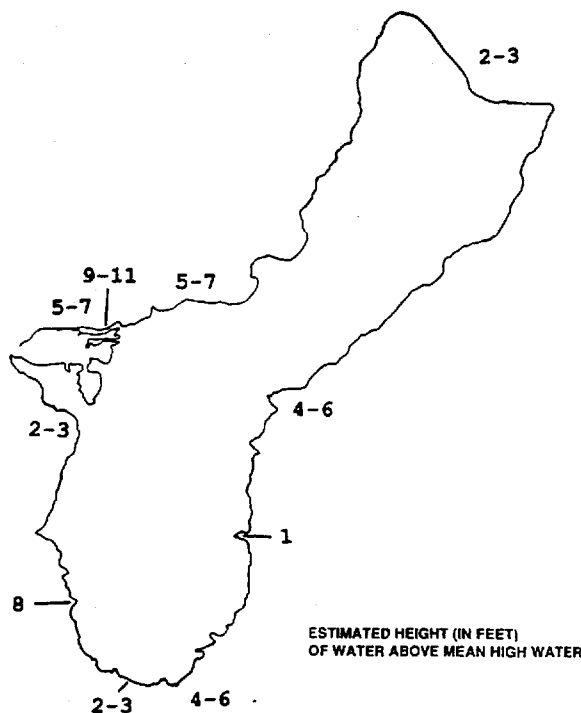


Figure 3-31-4. Estimates of the storm surge and wave runup experienced on Guam from the passage of Typhoon Gay on 23 November.

JTYM, EGRR, and CSUM all followed suit. Once Hunt recurved, the models, which had had trouble handling the two vortices, provided better guidance for Gay's track. By 26 November, as Gay approached the western extent of the mid-tropospheric subtropical ridge axis, most of the dynamic objective aids were back on track providing good guidance about the recurvature point and subsequent motion.

Gay was estimated to be the most intense tropical cyclone in the western North Pacific since Typhoon Tip in October 1979, and was identified early on as a probable rapid intensifier based on the tropical cyclone climatology for the location, time of year, sea surface temperature distribution and upper-tropospheric wind patterns. Prior to Gay's landfall on Guam, the Center also correctly predicted a decrease in intensity, due to the strong vertical wind shear from Typhoon Hunt (32W) to the north, but not nearly as fast as the weakening occurred. As Gay weakened, JTWC correctly anticipated the expansion of the typhoon's surface wind distribution and recommended that Conditions of Readiness 1 be set for the southern Mariana Islands of Guam, Rota, Tinian and Saipan. Reintensification after Gay passed to the west of Guam was also predicted based on the decreasing vertical wind shear from Hunt (32W).

#### IV. IMPACT

Gay bulldozed a path of destruction through most of the northern Marshall Islands, where the typhoon left over 5,000 people homeless, and knocked out power, water, and radio communications in Majuro. Miraculously, only one islander in the entire republic was injured, which reflects positively on the quality of the warning and disaster preparedness. President Amata Kabua declared Mejit Island and eight other northern atolls disaster areas. The hardest hit island was Wotho Atoll, population 160, where all trees and houses "fell down!" Amazingly, no one was injured as Gay ripped through the small atoll. Mejit Island fared only slightly better. They lost all wooden structures on the island, leaving almost all of the 445 people on that island homeless. The winds were so strong that most of the coconut trees



were blown down and 75% of the crops were lost. Ailuk Atoll suffered about the same crop losses as Mejit, but only had minor house damage. Utirik and Likiep Atolls suffered 50% crop and tree losses, and experienced damage to half of their houses. Maloelop and Aur Atolls were on the fringes of the damaging winds and only suffered 20 - 30% crop and house damage. Most of the atolls were without fresh drinking water for weeks or months after the typhoon, as catchment basins were destroyed or contaminated with salt water.

Majuro, the capital of the Marshall Islands, suffered from island-wide power outages due to lightning strikes. Another lightning strike hit the Outer Island Dispensary and knocked out the radio link to 67 of the outer island hospitals. One boat smashed into the seawall and sank as it broke loose in Majuro Harbor. For two days after Gay's passage, Air Marshall Island flights were canceled until the debris could be cleared from the runways.

Gay's next target was Guam. Passing over the center of the island, Gay became the fifth typhoon to pass within 60 nm (110 km) in less than three months, and everyone in the Marianas Islands took Gay's threat extremely seriously. Just to the north, Saipan recorded a record 1639 people in shelters as Gay passed, and twelve families had to be evacuated from their homes by emergency crews as the storm surge threatened to sweep away their houses. One house was destroyed by the storm surge and another was damaged by a fire caused by burning candles and kerosene lamps used after the power was out. On Tinian, four houses lost their sheet iron-roofs to Gay.

On Guam, it was difficult to isolate the damage from Gay alone because Typhoon Omar (15W) had already destroyed most of the weaker structures. The most visible result of Gay's passage over Guam was to the crops and vegetation on the island. Gay was a "dry" cyclone, and airborne salt whipped up from the ocean as the typhoon passed burnt the vegetation. Farmers suffered the most losses due to Typhoon Gay. The typhoon disrupted everyday life for the fifth time during the year: ships were sent to sea; 4,300 residents sought typhoon shelters; the port and airports were shut down; schools and other government and civilian offices were closed, and the power plant was placed in standby operation. The storm surge brought sand, coral rubble and water ashore, especially in the area of the Cabras Island port access road. Some wharf damage occurred when a fishing vessel broke loose from its mooring, and a fuel storage tank that was under construction collapsed. It must be remembered that it could have been worse, had it not been for the incredible timing of Typhoon Hunt's (32W) interaction with Gay, Guam would have had to face the devastation of a super typhoon.

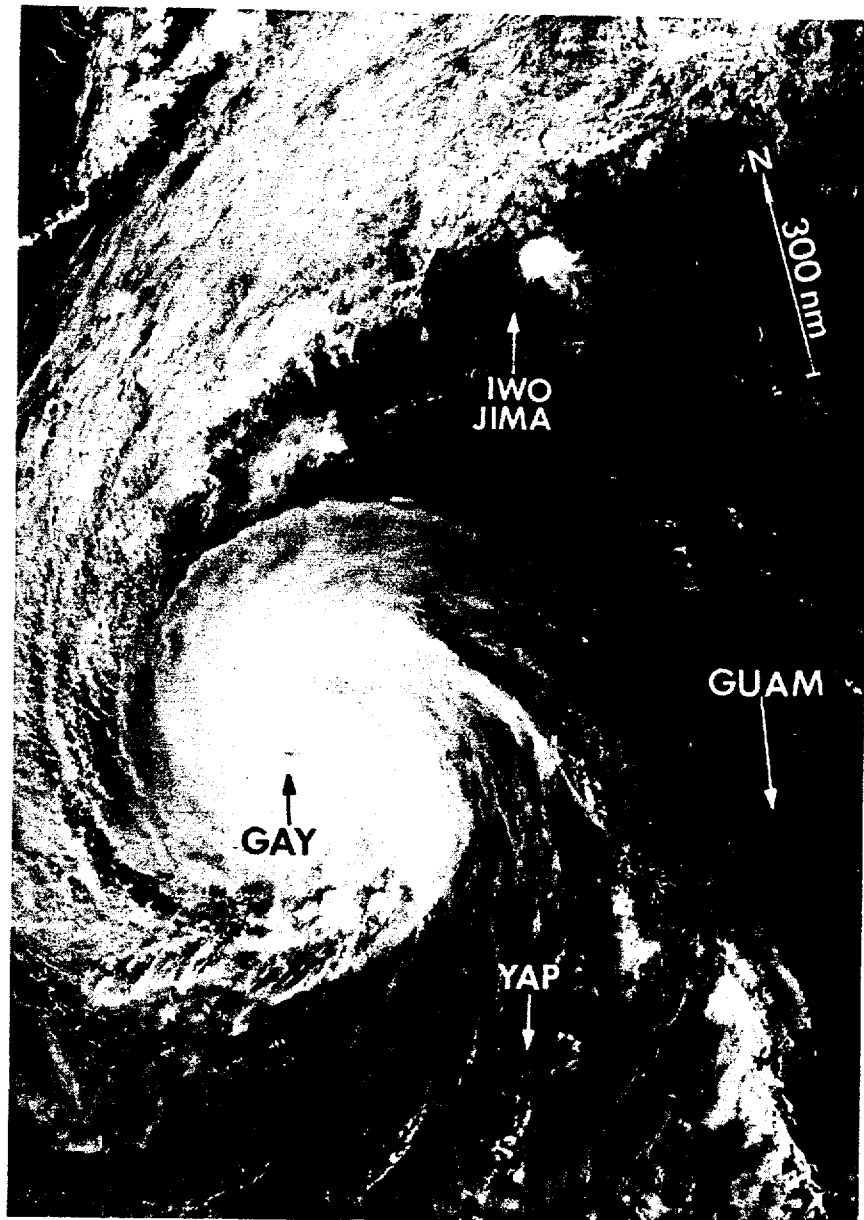


Figure 3-31-5. Gay's cloud filled eye is visible as the typhoon approaches it second peak intensity. The circulation is large which is typical of November typhoons (242348Z November DMSP visual imagery).

E 120 125 130 135 140 145 150 155 160 165 170 175 180

N 45

**TYPHOON HUNT**  
**BEST TRACK TC-32W**  
**13 NOV - 22 NOV 92**  
**MAX SFC WIND 125KT**  
**MINIMUM SLP 916MB**

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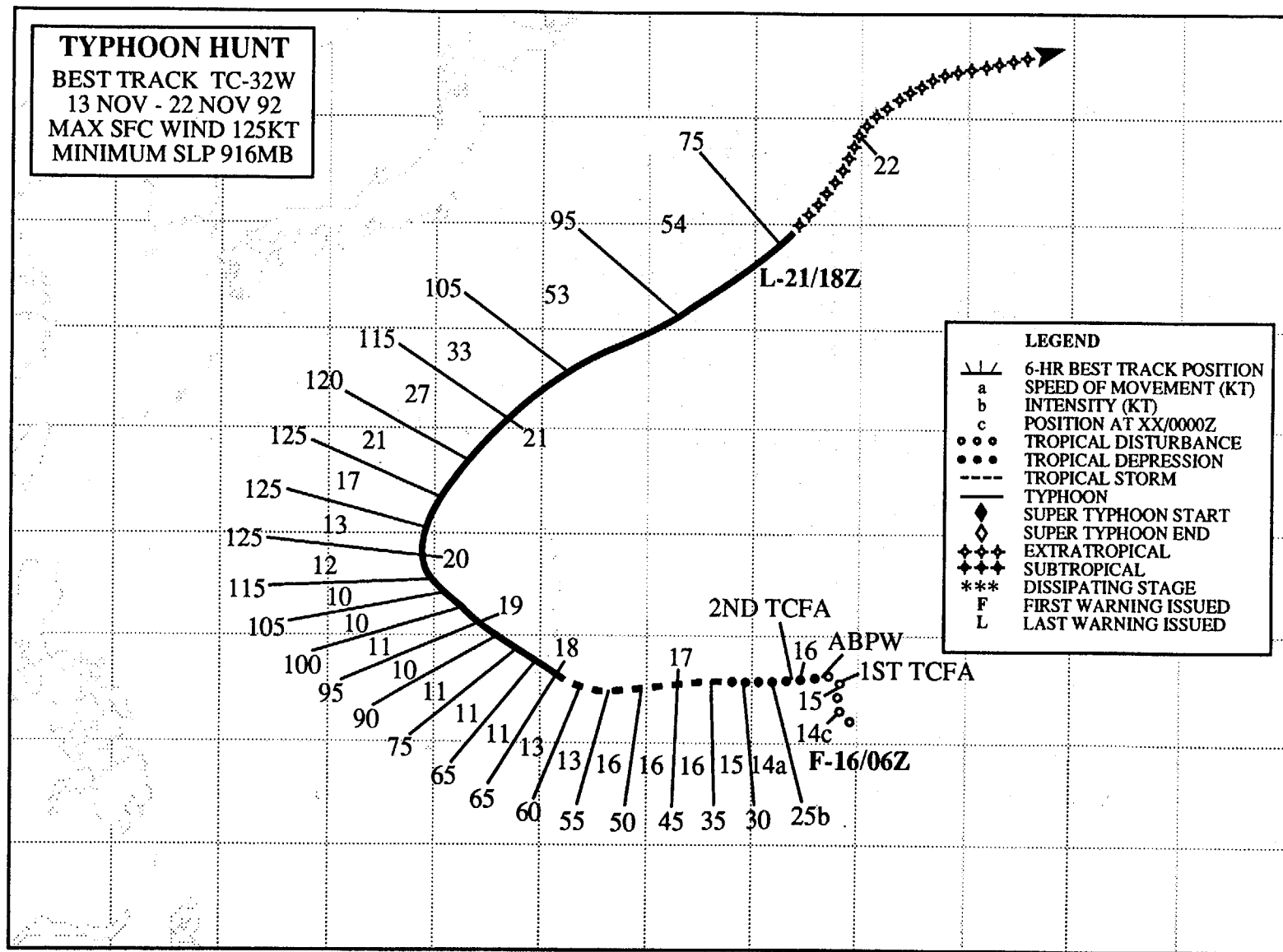
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## TYPHOON HUNT (32W)

### I. HIGHLIGHTS

The fourth typhoon to pass within 60 nm (110 km) of Guam in less than three months, Hunt was part of a three storm outbreak with Tropical Storm Forrest (30W) and Gay (31W). As Hunt intensified, it brushed by Guam, moved into the Philippine Sea, and later recurved. After recurvature, the typhoon played an important role in the extremely rapid weakening of Super Typhoon Gay (31W) which was approaching the southern Mariana Islands.

### II. TRACK AND INTENSITY

On 13 November, the monsoon trough extended eastward from Tropical Storm Forrest (30W) in the South China Sea, across the southern Philippines, through the Caroline Islands to a tropical disturbance in the southern Marshall Islands, and on further to the another tropical disturbance forming just to the east of the international dateline that would become Gay (31W). The tropical disturbance in the southern Marshall Islands that became Hunt was first mentioned by JTWC on the 140600Z November Significant Tropical Weather Advisory. As the cloud system associated with this disturbance slowly drifted northward, increasing convection prompted JTWC to issue the first Tropical Cyclone Formation Alert at 150400Z. Because the disturbance was slow to consolidate, the alert was reissued at 160400Z. The first warning followed at 160600Z based on the appearance of a poorly defined low-level circulation center with improved convective organization on the animated visual and infrared satellite imagery.

Tropical Depression 32W tracked westward under the steering influence of the mid-tropospheric subtropical ridge. Intensifying at an average rate of one Dvorak T-number per day, the depression was upgraded by JTWC to Tropical Storm Hunt at 170000Z. Twenty-four hours later, Hunt was further upgraded to a typhoon based on an Dvorak intensity estimate of 65 kt (33 m/sec), and convective organization that had continued to improve.

As Hunt approached Guam, it was expected to pass close to, or over, the southern portion of the island. However, to the east of the island, the typhoon changed course and began to track northwestward toward a break in the subtropical ridge. The typhoon passed 10 nm (20 km) east-northeast of Andersen AFB (WMO 91218) where a minimum sea-level pressure of 987.2 mb was recorded at 180455Z. After Hunt churned through the channel between the islands of Guam and Rota, a strong convective band crossed Guam producing two to three hours of 60 kt (31 m/sec) winds with gusts to 75 kt (39 m/sec), and heavy rain.

Continuing to intensify on its northwestward track, Hunt reached a peak of 125 kt (64 m/sec) near its point of recurvature at 200000Z (Figure 3-32-1). The typhoon's acceleration into the mid-latitude westerlies was one of the fastest noted in 1992 or any year, reaching an average 6-hour track speed of 54 kt (100 km/hr) as it transitioned into an extratropical low. (See the Super Typhoon Gay (31W) synopsis for a more complete description of Hunt's affect on Gay (31W).) The final warning for Hunt was issued by JTWC at 211800Z when Hunt became extratropical.

### III. FORECAST PERFORMANCE

The overall mean track errors for JTWC were 145, 300 and 545 nm (265, 556 and 1010 km) for the 24-, 48- and 72-hour forecasts. This performance was much worse than average and was beaten by CLIPER at 48 and 72 hours. The poor overall performance resulted from several factors. First, over estimation of the strength of the subtropical ridge led to steady westward track forecasts, even after

Hunt began to move northwestward. Second, forecasters were heavily influenced by the NOGAPS guidance which had a difficult time resolving both the circulations of Typhoon Hunt and Super Typhoon Gay (31W), and erroneously indicated that Hunt would stall as Gay (31W) recurved first and accelerated into the westerlies. Finally, the greatest errors at 48 and 72 hours were due to under forecasting Hunt's unusually rapid acceleration after recurvature.

Overall intensity forecasts were good with the exception of the 72-hour extended outlooks for the first four warnings. These proved to be 45 to 50 kt (23 to 26 m/sec) too low when an anticipated increase in vertical shear did not occur, and Hunt intensified more rapidly than expected.

#### IV. IMPACT

In preparation for Hunt's passage on 18 November, Guam boarded up, closed schools and other government offices, evacuated aircraft, and sent ships to sea. The disaster preparations paid off. No fatalities or injuries were reported and damage appeared to minimal, however, the quantitative assessments of the minor damage caused by Hunt were not completed before Super Typhoon Gay (31W) slammed into the island five days later. As with Brian (25W) and Elsie (28W), more damage would have occurred had not Omar (15W) destroyed most of the island's weaker structures earlier on 28 August.

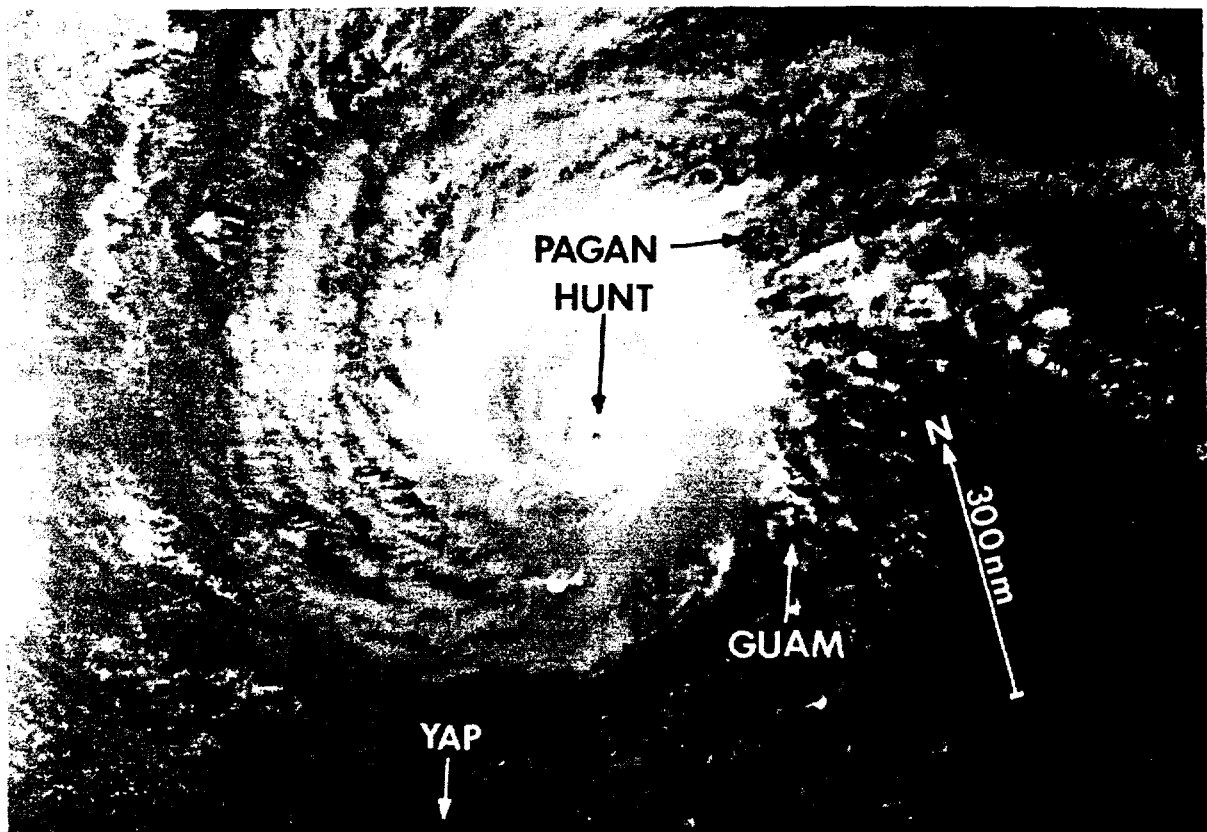


Figure 3-32-1. As Hunt intensifies, the diameter of its cloud-filled eye, which had been 14 nm (26 km) nine hours earlier, decreases to 7 nm (13 km) (182336Z November DMSP visual imagery).

### 3.3 NORTH INDIAN OCEAN TROPICAL CYCLONES

Spring and fall in the North Indian Ocean are periods of transition between major climatic controls and the most favorable seasons for tropical cyclone activity (Tables 3-5 and 3-6). This year was the most active North Indian Ocean tropical cyclone season since JTWC started issuing warnings for the region in 1971. A record 12 tropical cyclones formed in the North Indian Ocean, 4 in the Arabian Sea and 8 in the Bay of Bengal. A total of 13 cyclones transited the North Indian Ocean if you count Typhoon Forrest (30W) that crossed from the Gulf of Thailand into the Bay of Bengal. This was well above the 5 per year average, and 4 more than the previous record of 8 tropical cyclones in 1987.

The JTWC was in warning status a total of 53 days, 34 more days than last year. Also, JTWC was in warning status on 2 tropical cyclones simultaneously, Tropical Cyclone 10B and Typhoon 30W (Forrest), for a 3-day period in November. For the 22-year period of record, Tropical Cyclone 04B became the first tropical cyclone to occur in July, leaving March as the only month without a recorded tropical cyclone. Also, a record-breaking 3 tropical cyclones occurred in October and then again in November. Tropical Cyclone 12A was the last cyclone of the year and caused delays for ships transiting the Arabian Sea in support of OPERATION RESTORE HOPE. Composite best tracks for the North Indian Ocean tropical cyclones for 1992 are shown in Figure 3-9.

TABLE 3-5.

1992 SIGNIFICANT TROPICAL CYCLONES  
NORTH INDIAN OCEAN

TROPICAL CYCLONE	PERIOD OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/SEC)	ESTIMATED MSLP (MB)
TC 01B	16 MAY - 20 MAY	15	65 (33)	976
TC 02A	05 JUN - 12 JUN	29	35 (18)	997
TC 03B	17 JUN - 18 JUN	6	45 (23)	991
TC 04B	26 JUL - 27 JUL	4	40 (21)	994
TC 05B	22 SEP - 24 SEP	7	30 (15)	1000
TC 06A	01 OCT - 03 OCT	10	55 (28)	984
TC 07B	07 OCT - 09 OCT	10	45 (23)	991
TC 08B	21 OCT - 21 OCT	3	30 (15)	1000
TC 09B	03 NOV - 07 NOV	20	55 (28)	984
TC 10B	11 NOV - 17 NOV	28	70 (36)	972
TC 30W	15 NOV - 22 NOV	26	125 (64)	916
TC 11A	30 NOV - 03 DEC	14	50 (26)	987
TC 12A	20 DEC - 24 DEC	18	50 (26)	987

TOTAL: 190

TABLE 3-6. NORTH INDIAN OCEAN TROPICAL CYCLONES DISTRIBUTION

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1971*	-	-	-	-	-	0	0	0	0	1	1	0	2
1972*	0	0	0	1	0	0	0	0	2	0	1	0	4
1973*	0	0	0	0	0	0	0	0	0	1	2	1	4
1974*	0	0	0	0	0	0	0	0	0	0	1	0	1
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
1977	0	0	0	0	1	1	0	0	0	1	2	0	5
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
1981	0	0	0	0	0	0	0	0	0	1	1	1	3
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
1987	0	1	0	0	0	2	0	0	0	1	2	2	8
1988	0	0	0	0	0	1	0	0	0	1	2	1	5
1989	0	0	0	0	1	1	0	0	0	0	1	0	3
1990	0	0	0	1	1	0	0	0	0	0	1	1	4
1991	1	0	0	1	0	1	0	0	0	0	1	0	4
1992	0	0	0	0	1	2	1	0	1	3	3	2	13

(1975-1992)

AVERAGE: 0.2 0.1 0.0 0.2 0.7 0.6 0.0 0.0 0.3 0.9 1.5 0.6 5.0  
TOTAL: 3 1 0 3 12 11 1 1 4 17 27 10 90

\* JTWC WARNING RESPONSIBILITY BEGAN ON 4 JUNE 1971 FOR THE BAY OF BENGAL, EAST OF 90° EAST LONGITUDE. AS DIRECTED BY CINCPAC, JTWC ISSUED WARNINGS ONLY FOR THOSE TROPICAL CYCLONES THAT DEVELOPED OR TRACKED THROUGH THAT PART OF THE BAY OF BENGAL. IN 1975, JTWC'S AREA OF RESPONSIBILITY WAS EXTENDED WESTWARD TO INCLUDE THE WESTERN PART OF THE BAY OF BENGAL AND THE ENTIRE ARABIAN SEA.

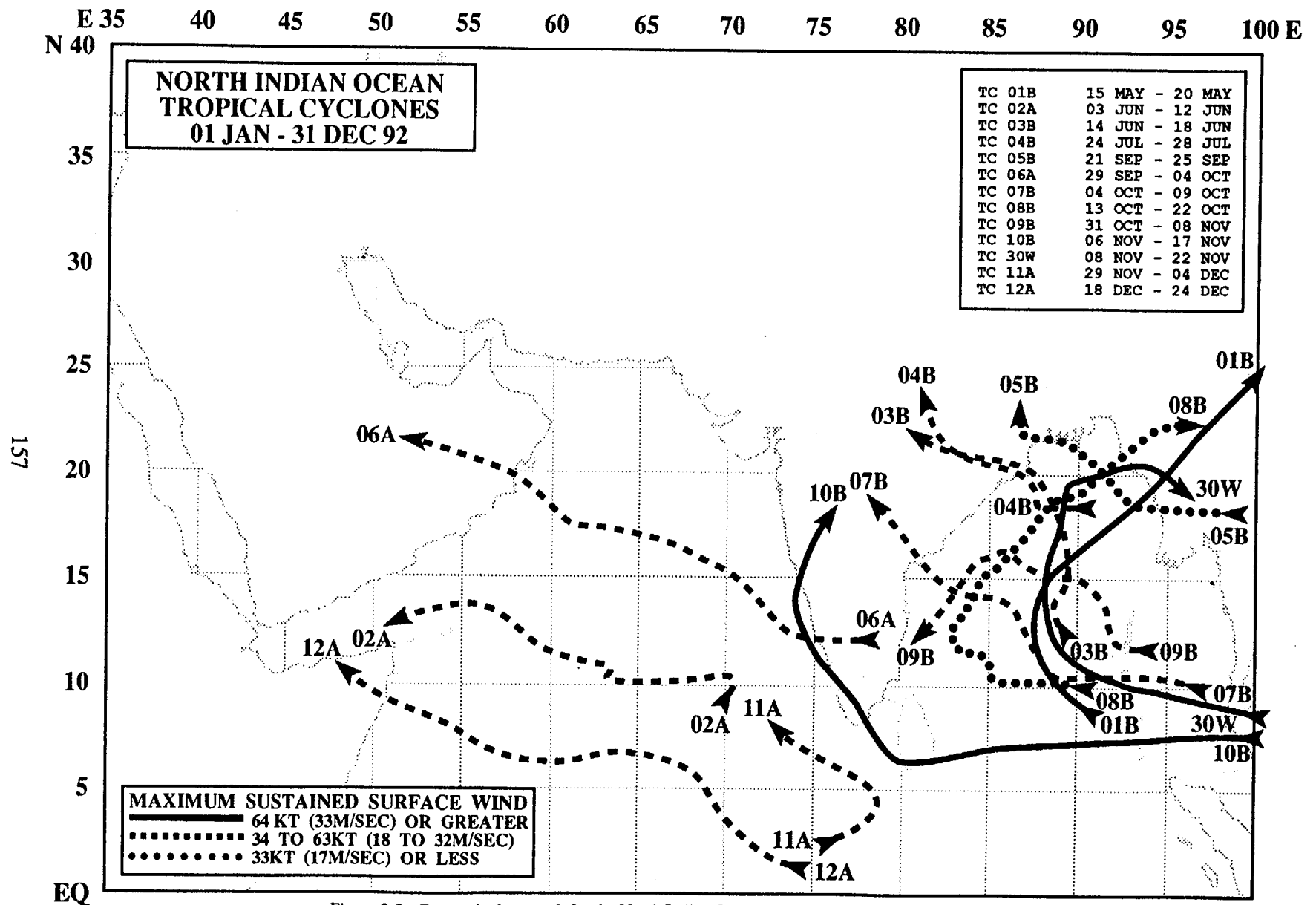
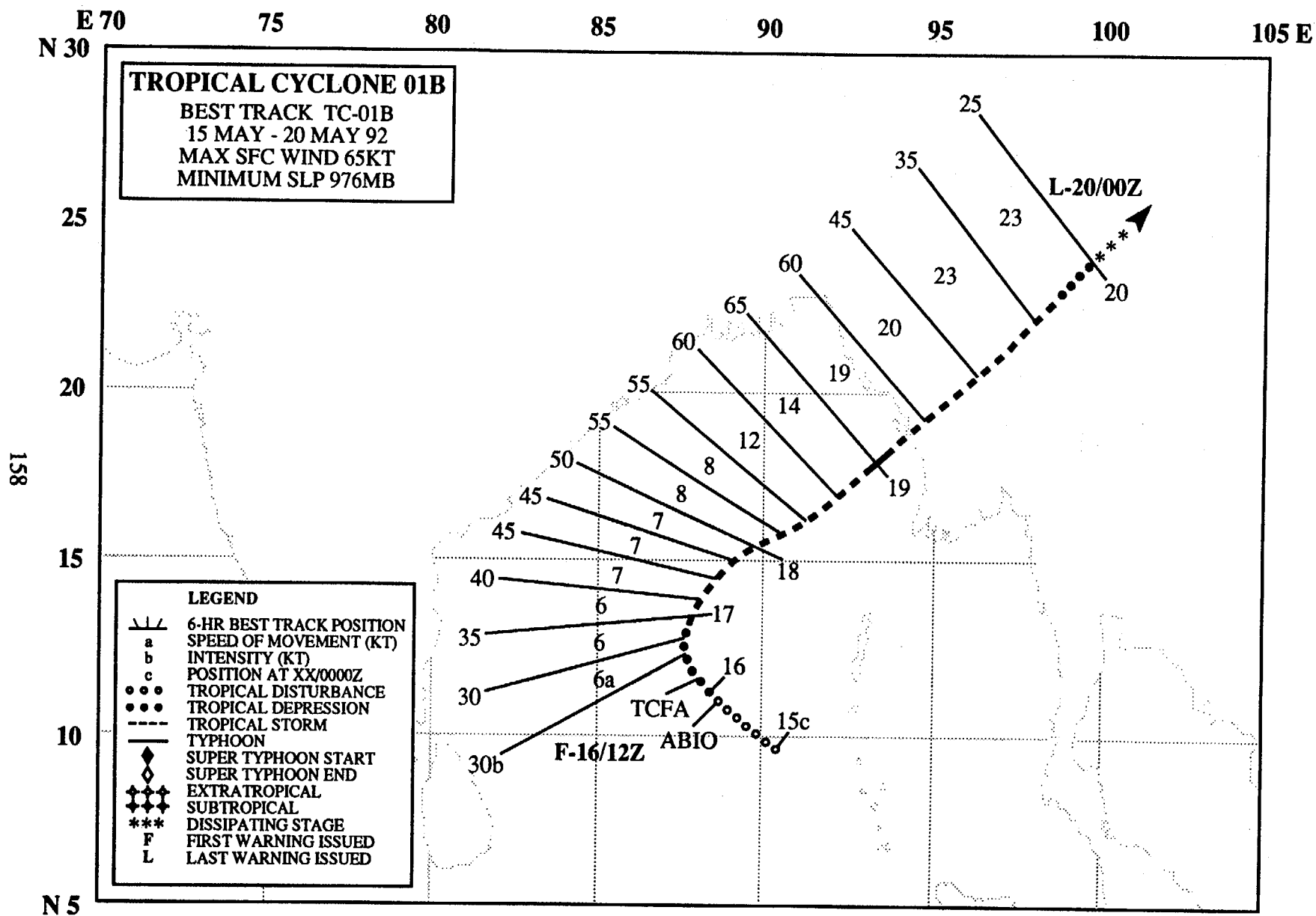


Figure 3-9. Composite best track for the North Indian Ocean tropical cyclones for 1992.





## TROPICAL CYCLONE 01B

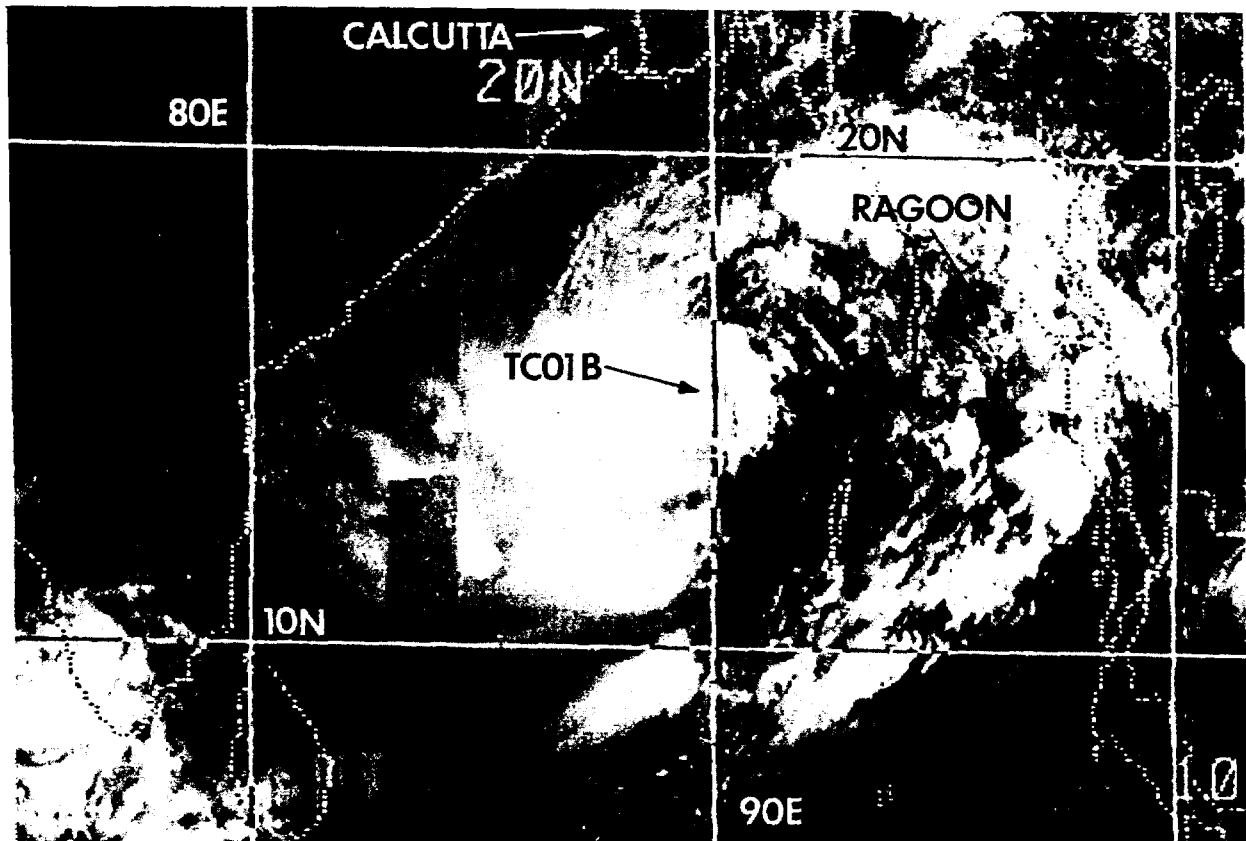
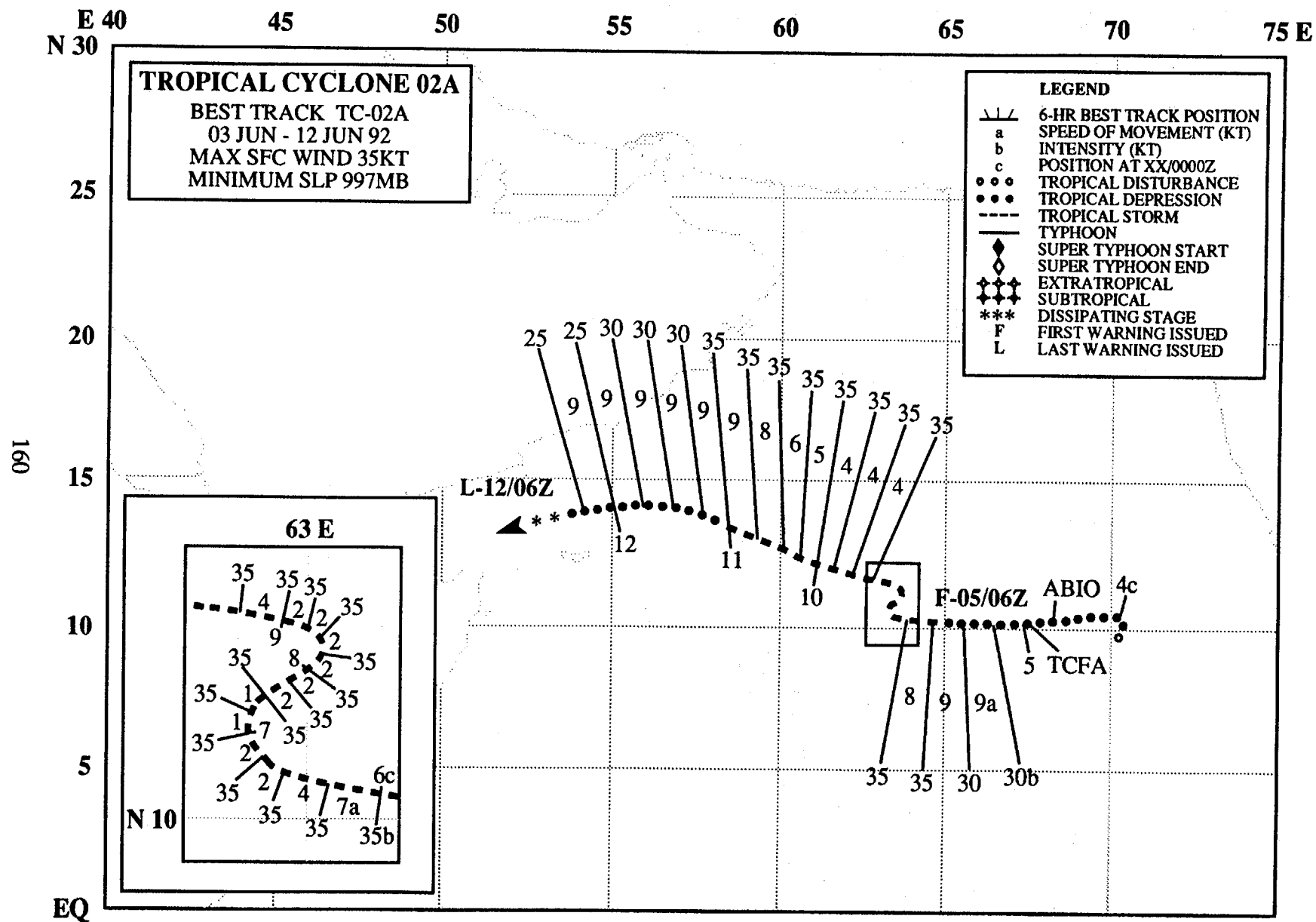


Figure 3-01B-1. Although TC01B's central dense overcast is located near the center of the Bay of Bengal, a broad band of enhanced cloudiness associated with the tropical cyclone is already affecting Burma (180200Z - 180400Z May DMSP visual digitized mosaic).

After an absence of tropical cyclone activity in the North Indian Ocean for six months, TC01B developed in the Bay of Bengal with the onset of the summer monsoon. It was first mentioned on the 151800Z May Significant Tropical Weather Advisory and was the subject of a Tropical Cyclone Formation Alert at 160451Z, which was followed by the first warning at 161200Z. Because of the slow intensification and poorly defined cloud system center of TC01B, JTWC had to relocate the initial position on the second warning. The system recurved on 16 May, and continued to intensify afterward, reaching minimal typhoon intensity for a short period prior to landfall in Burma on 19 May. The final warning was issued by JTWC at 200000Z.



## TROPICAL CYCLONE 02A

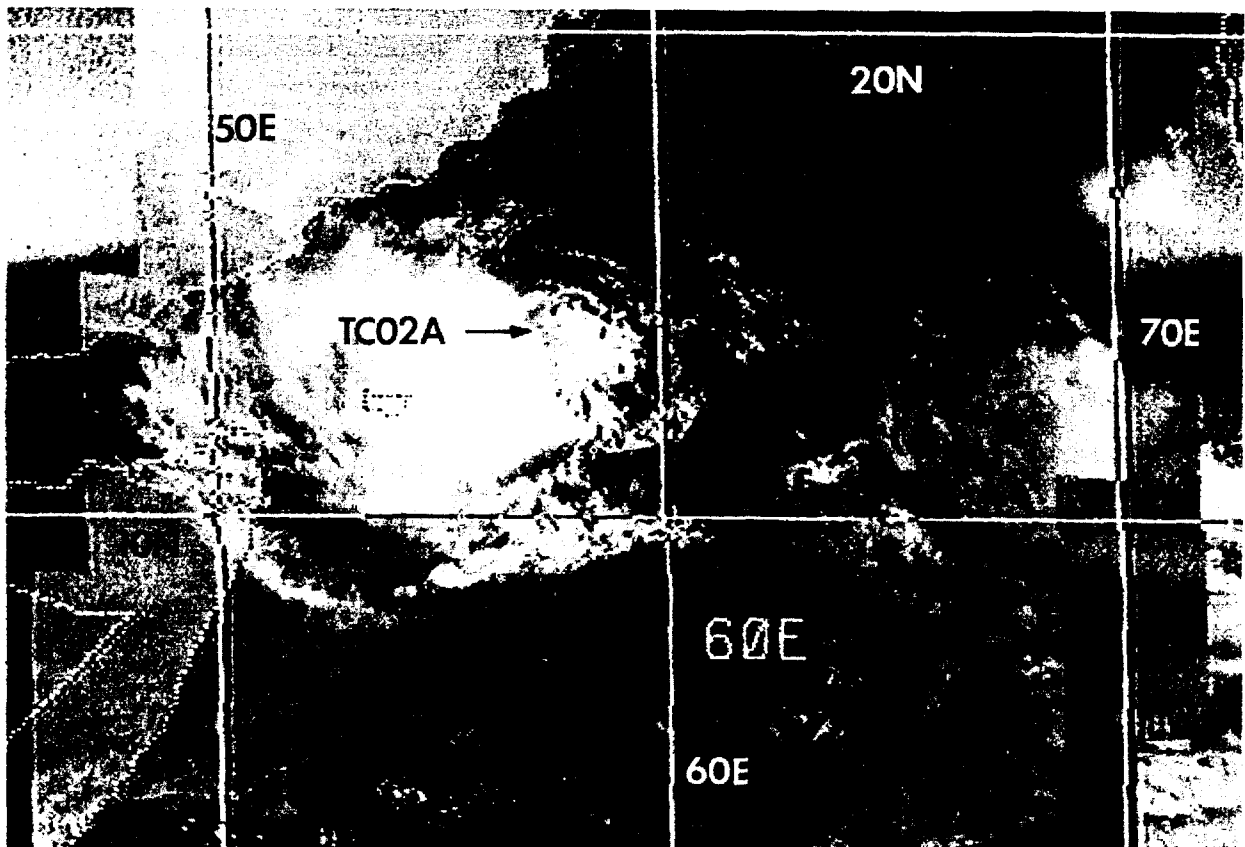
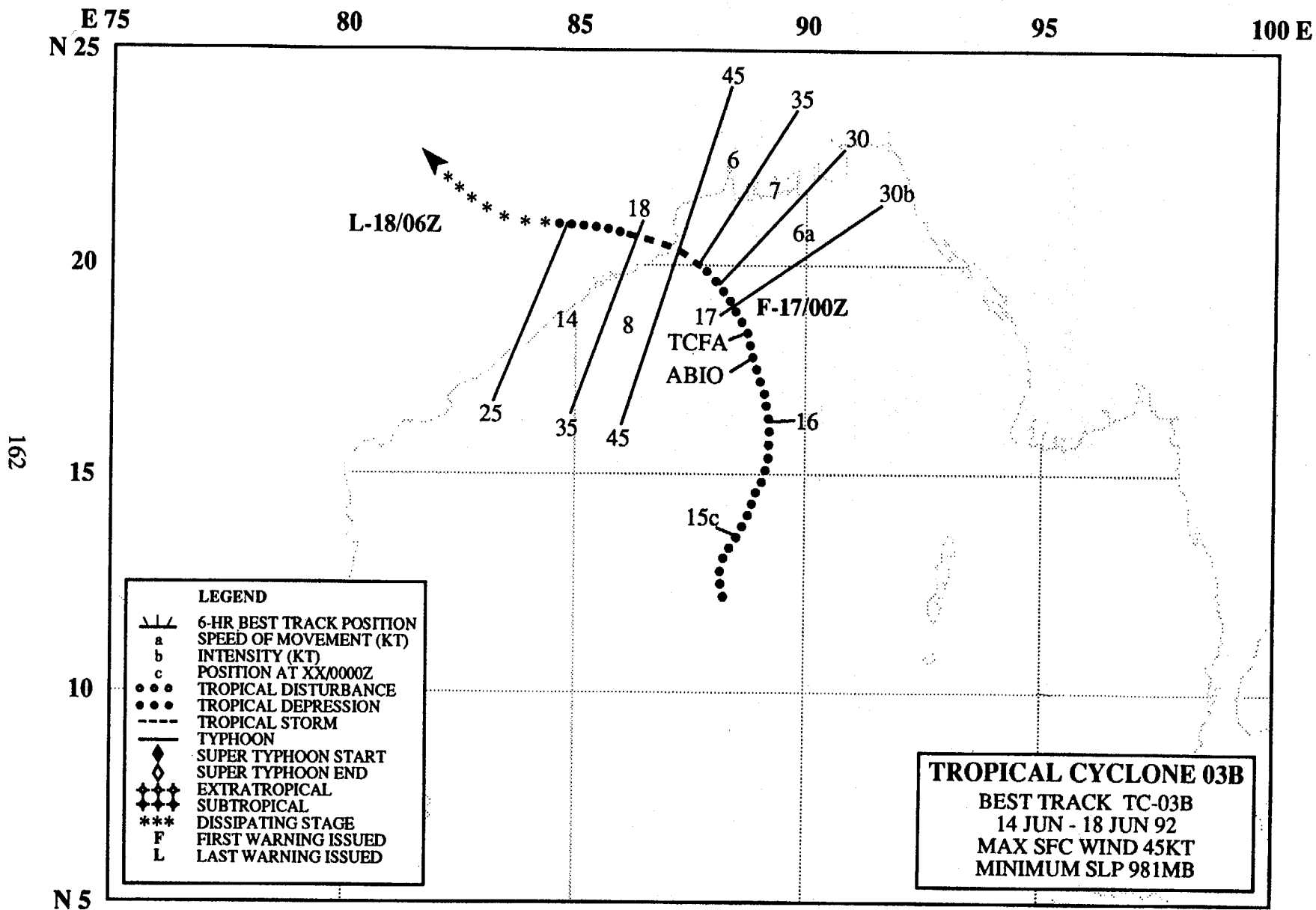


Figure 3-02A-1. A partially exposed low-level circulation is visible to the east of TC02A's central cloud mass (110300Z - 110400Z June DMSP visual digitized mosaic).

Two weeks after TC01B formed in the Bay of Bengal, a small low-level circulation center developed in the monsoon trough in the Arabian Sea. Increasing convection prompted JTWC to mention it on the 041800Z June Significant Tropical Weather Advisory. As convective organization rapidly improved, this was followed by a Tropical Cyclone Formation Alert at 042300Z, and the first warning at 050600Z. However, strong upper-level easterly winds restricted the outflow aloft, keeping the cyclone at minimum tropical storm intensity over the next five days as it tracked slowly westward across the Arabian Sea. Interpretation of DMSP microwave imagery on 7 June indicated that the low-level circulation was further east than analyzed from infrared data, resulting in a relocated position and an amended forecast at 072100Z. As the presence of upper-level shear persisted, TC02A gradually weakened. The final warning was issued by JTWC at 120600Z as the cyclone dissipated over the open ocean just north of the island of Socotra. TC02A was the first of four tropical cyclones to develop during 1992 in the Arabian Sea, a basin that averages only one per year



## TROPICAL CYCLONE 03B

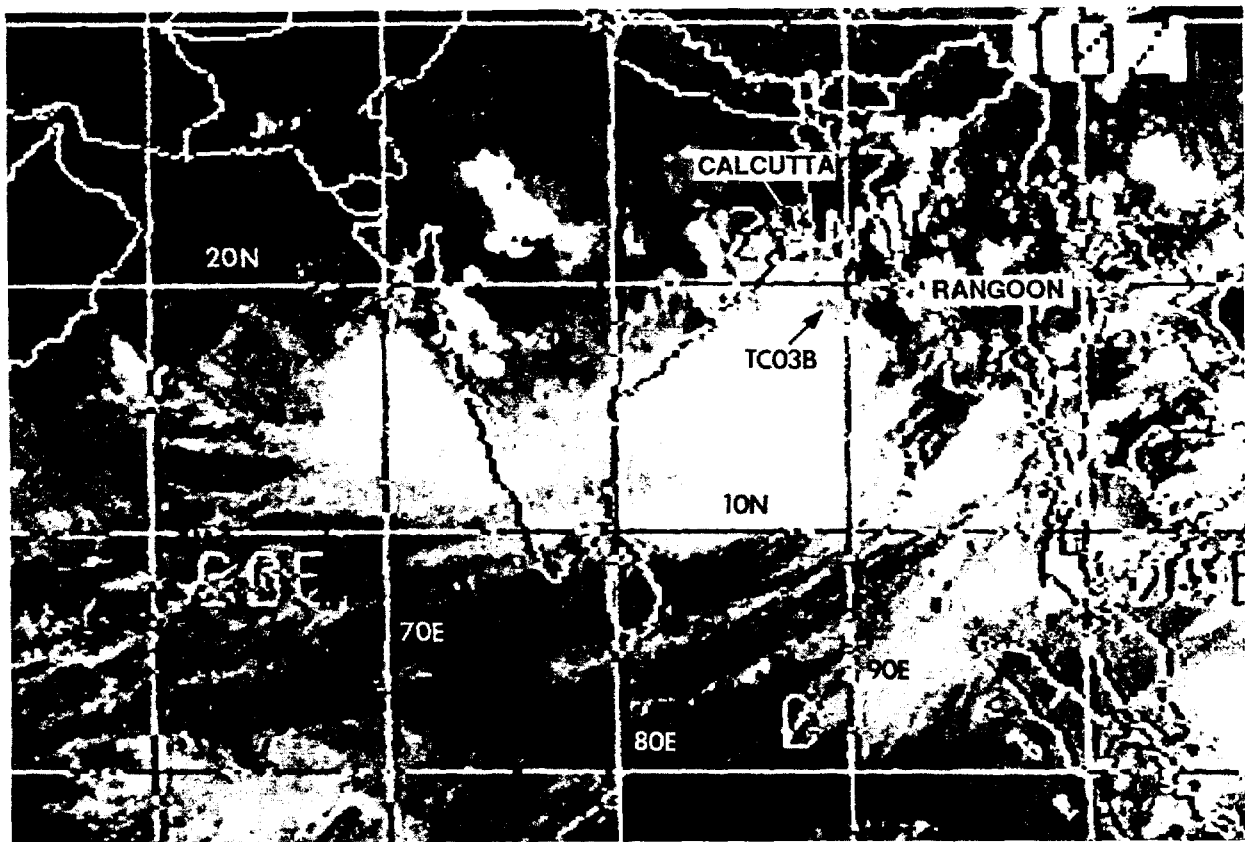


Figure 3-03B-1. TC03B a day before making landfall in India (161000Z - 161200Z June DMSP infrared digitized mosaic).

In response to a surge in the monsoon the second week of June, a tropical disturbance developed in the Bay of Bengal which prompted JTWC to reissue the Significant Tropical Weather Advisory for the Indian Ocean at 161300Z June to include mention of the disturbance's consolidation. A Tropical Cyclone Formation Alert followed at 161800Z, and the first warning was issued by JTWC at 170000Z as the cyclone turned northwestward towards India. Due to its nearness to the coast of India, TC03B had little time to intensify. The tropical cyclone struck the coast with a peak intensity of 45 kt (23 m/sec) at 172000Z, and slowly dissipated overland. JTWC issued the final warning at 180600Z.

E 75 80 85 90 95 E  
N 25

20

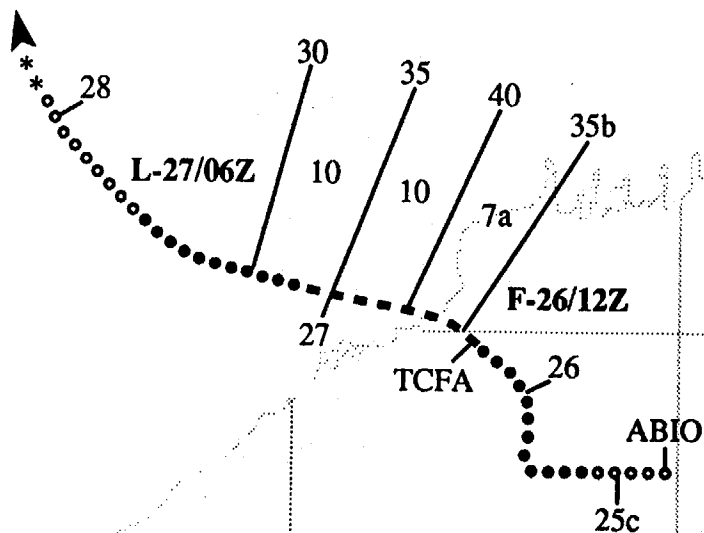
164

15

N 10

# **TROPICAL CYCLONE 04B**

BEST TRACK TC-04B  
24 JUL - 28 JUL 92  
MAX SFC WIND 40KT  
MINIMUM SLP 985MB



## **LEGEND**

- 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

## TROPICAL CYCLONE 04B

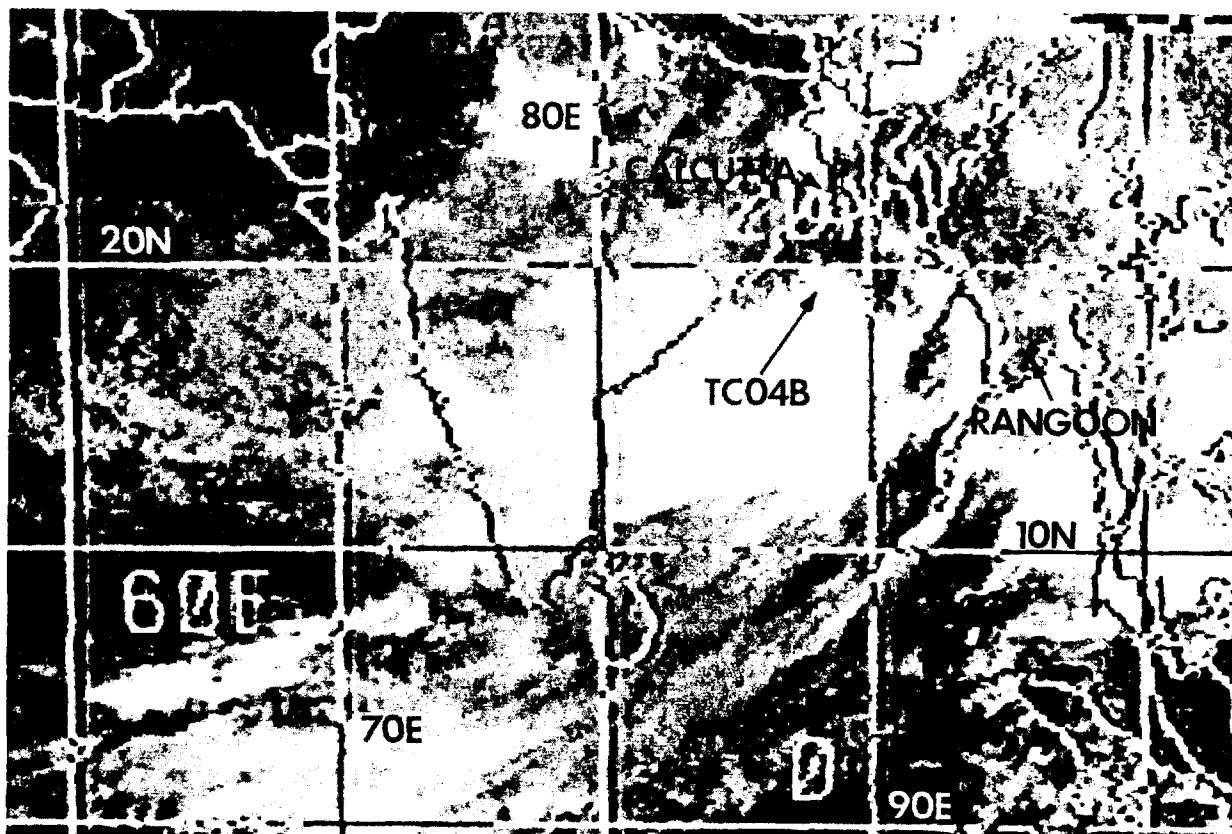
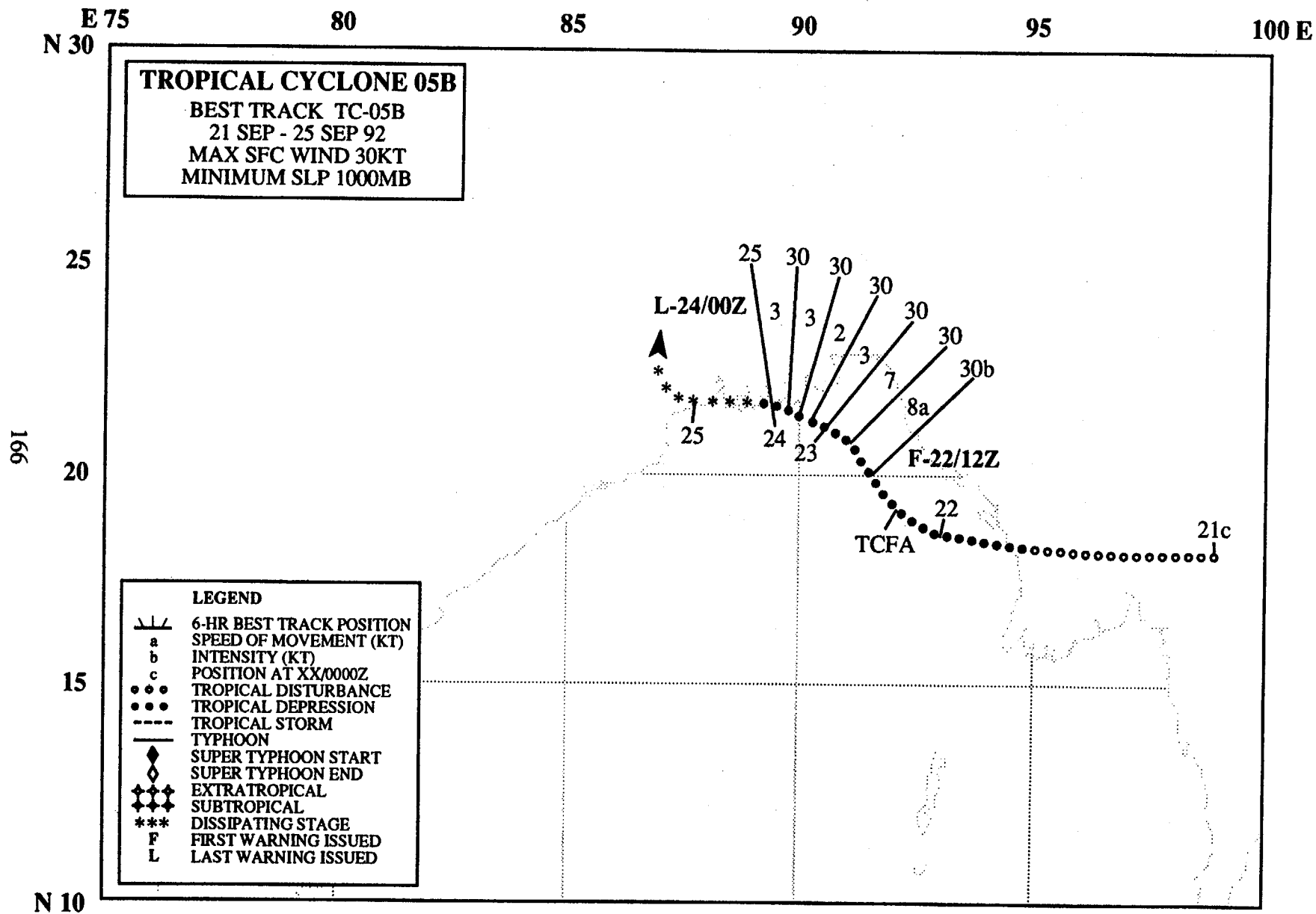


Figure 3-04B-1. The deep convection and torrential rains associated with TC04B are located to the south of the circulation center, a result of strong vertical wind shear between low-level convergent and high-level divergent winds (252300Z - 260100Z July DMSP infrared digitized mosaic).

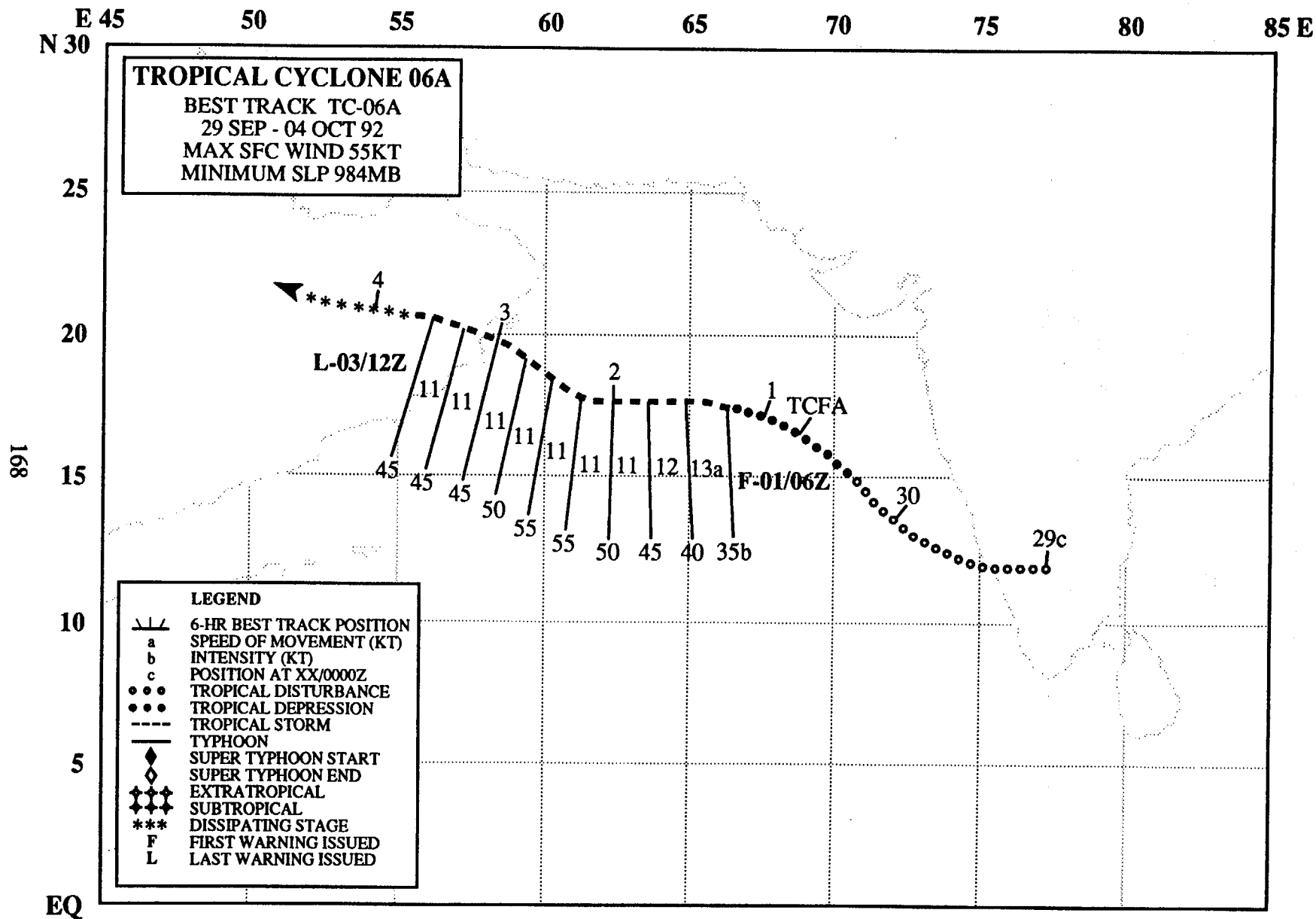
A rare July cyclone in the Bay of Bengal, TC04B followed a track very similar to Tropical Cyclone 03B in June. The tropical disturbance was first mentioned by JTWC on the 241800Z July Significant Tropical Weather Advisory. As the southwesterly monsoonal surge increased in strength, TC04B intensified, prompting JTWC to issue a Tropical Cyclone Formation Alert at 261000Z. The first warning followed almost immediately at 261200Z based on the extent of the surge and surface pressure falls on the coast of India. TC04B reached a peak intensity of 40 kt (21 m/sec) at landfall. As the tropical cyclone slowly weakened overland, JTWC issued the final warning at 270600Z.





## **TROPICAL CYCLONE 05B**

After a two month hiatus of tropical cyclone activity in the North Indian Ocean, the tropical disturbance that became TC05B moved into the Bay of Bengal and developed on 21 September. As the broad monsoon depression moved over open water in the Bay of Bengal and its convection increased, JTWC went directly to a Tropical Cyclone Formation Alert at 220525Z. Within the next six hours, the increased convection had organized and the Center issued the first warning at 221200Z. TC05B remained close to the shoreline of Bangladesh and India and did not intensify above 30 kt (15 m/sec). The final warning was issued by JTWC at 240000Z as the tropical cyclone dissipated over land.



## TROPICAL CYCLONE 06A

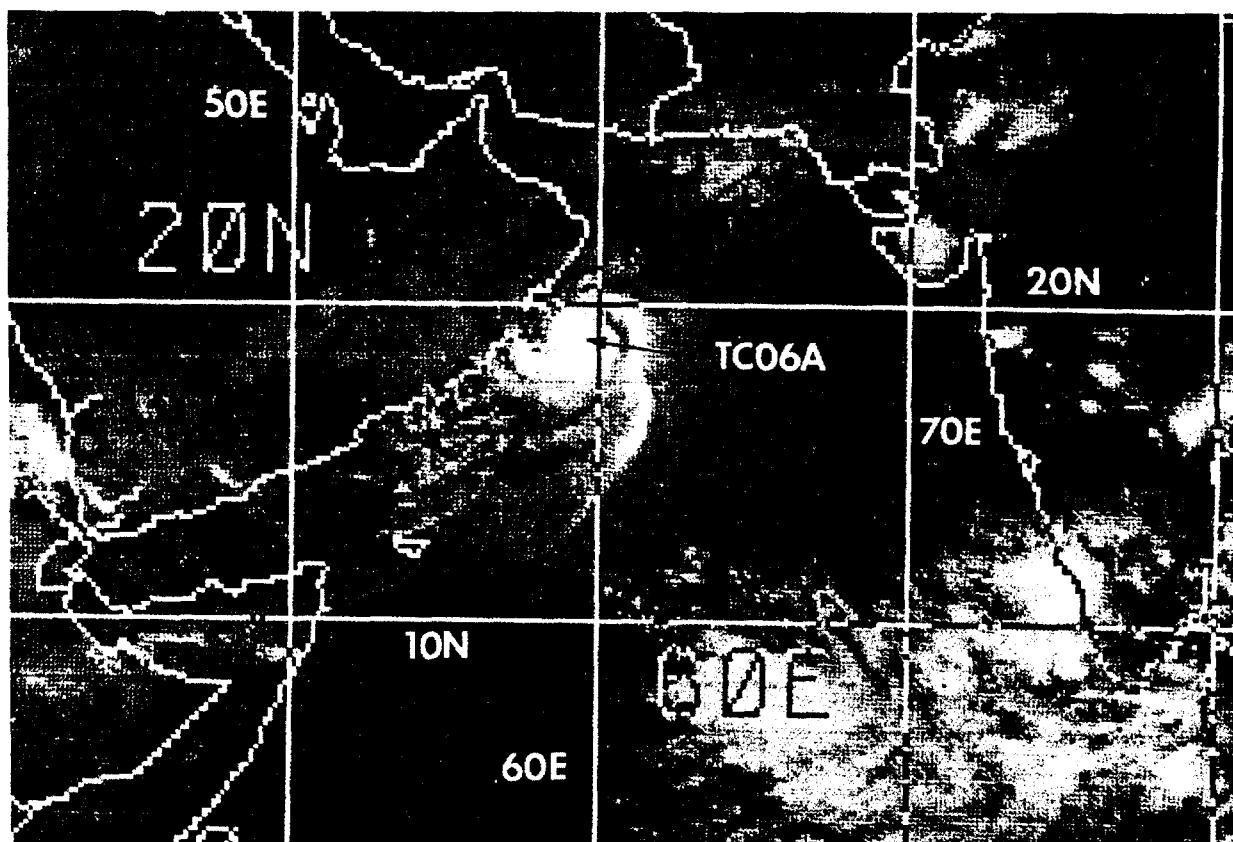
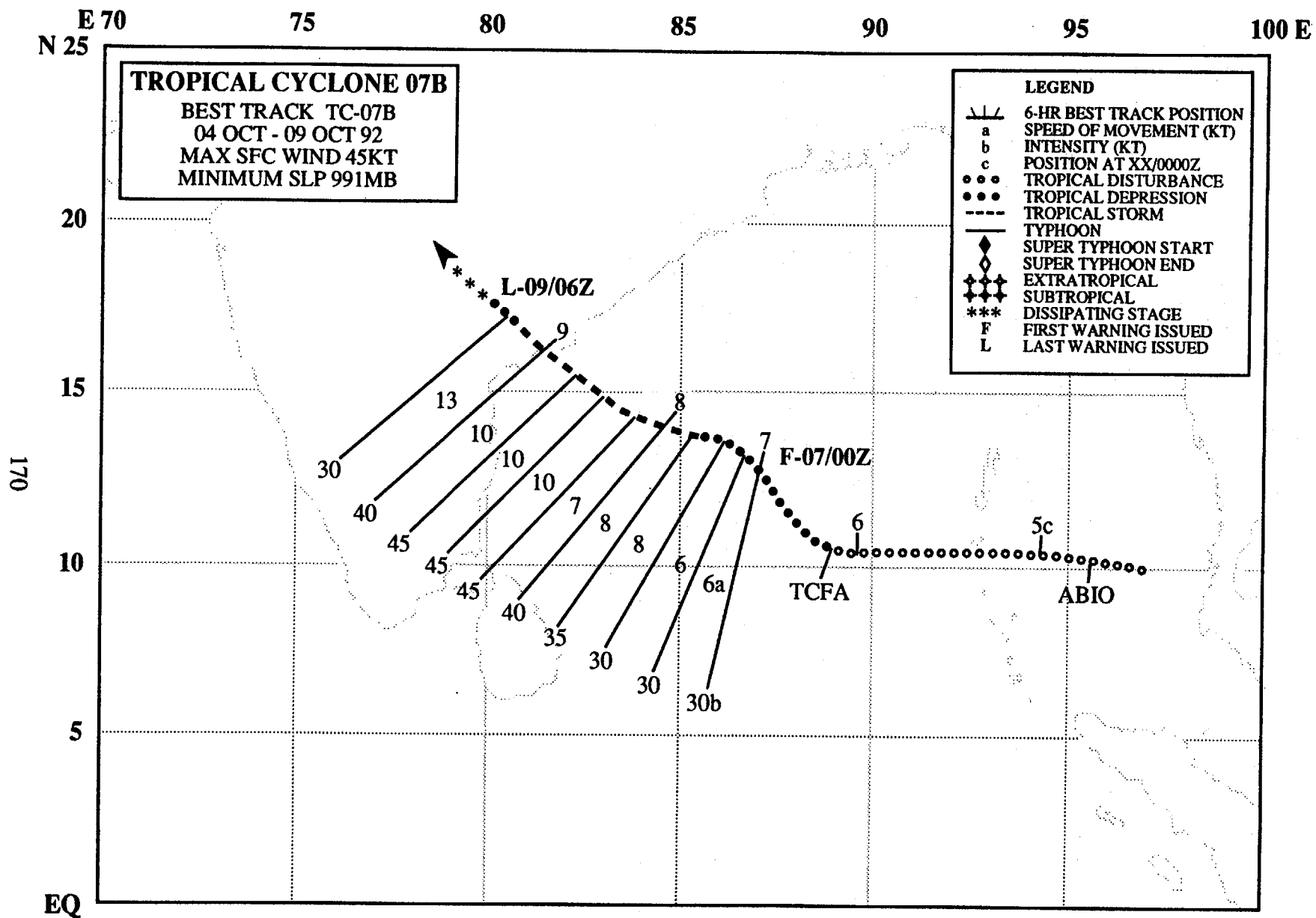


Figure 3-06A-1. Near peak intensity, TC06A approaches landfall on Oman (021600Z - 021800Z October DMSP infrared digitized mosaic).

An area of low pressure which developed over southern India moved offshore, tracking west-northwestward across the Arabian Sea. Because of strong easterly winds aloft, most of the deep convection associated with the tropical disturbance was displaced west of its poorly defined surface circulation center. As a consequence, the tropical cyclone developed slowly. Eventually, increased organization in the low-level circulation center required JTWC to issue a 301800Z September Tropical Cyclone Formation Alert. The first warning followed at 010600Z. TC06A continued to intensify as it tracked west-northwestward reaching a peak intensity of 55 kt (28 m/sec) approximately 250 nm (465 km) off the coast of Oman. Land interaction and vertical wind shear increased as it tracked closer to the Arabian Peninsula, shearing the low level away from the upper-level circulation center. As TC06A dissipated over Oman, the last warning by JTWC was issued at 031200Z.



## TROPICAL CYCLONE 07B

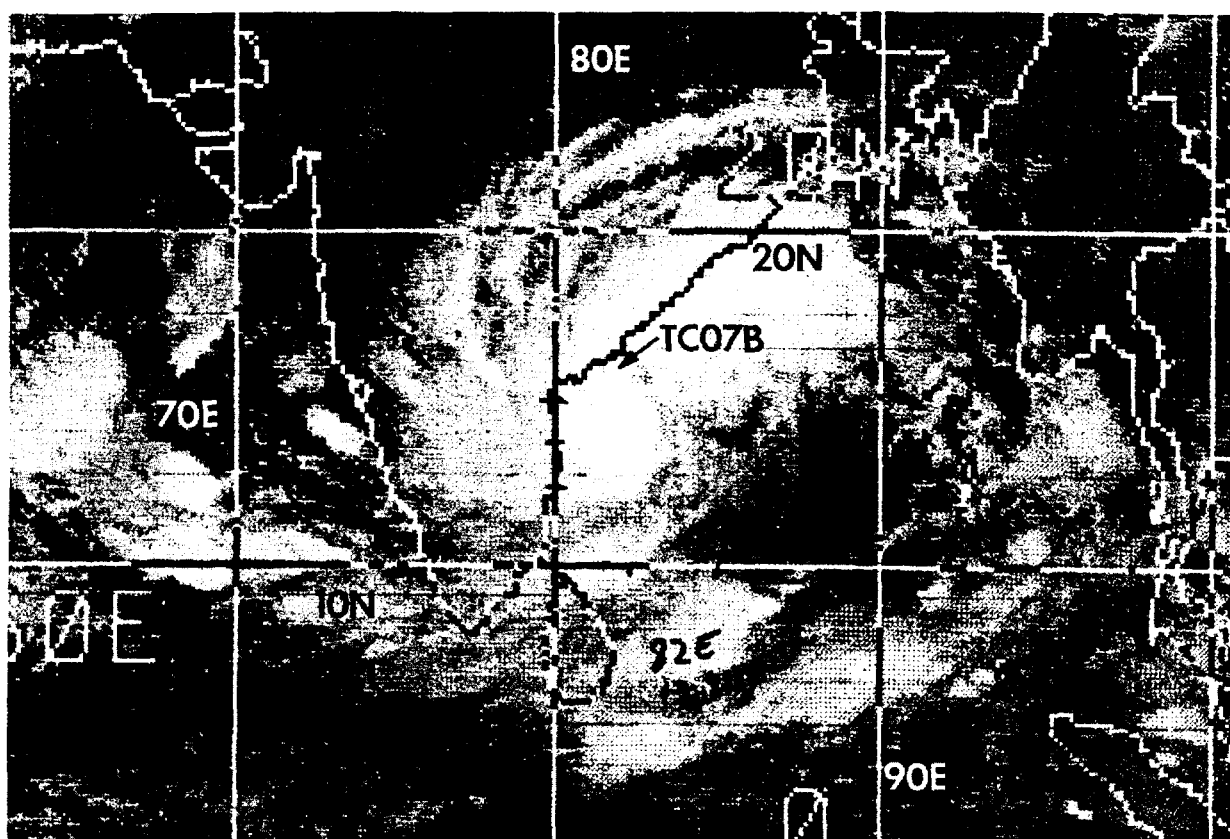
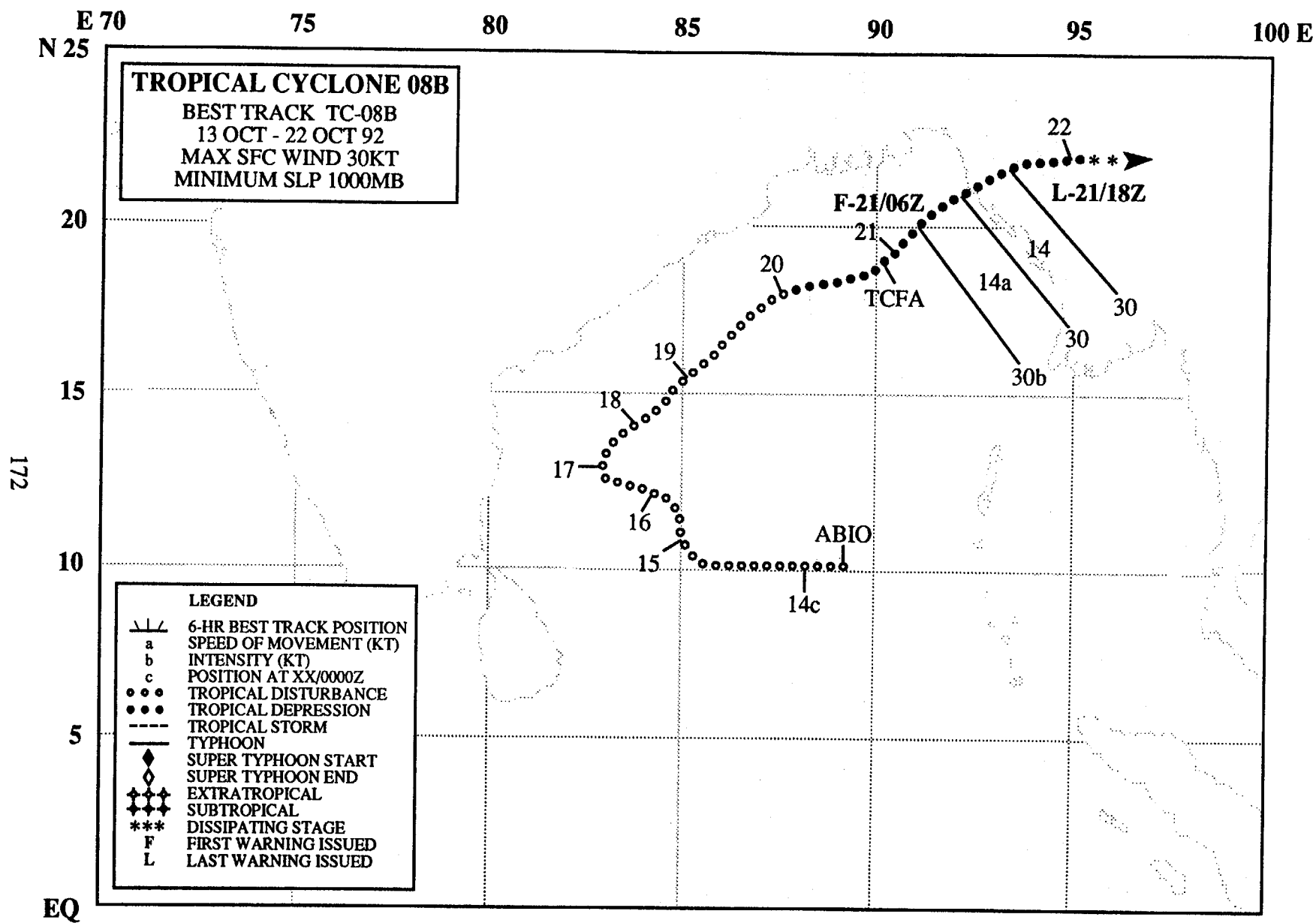


Figure 3-07B-1. At peak intensity, TC07B nears the coast of India (082200Z October DMSP infrared digitized mosaic).

A southwesterly surge into the Andaman Sea resulted in the development of the tropical disturbance that became TC07B. Continued support from a receding southwesterly monsoonal flow led to intensification of the disturbance which was first mentioned by JTWC on the 041800Z October Significant Tropical Weather Advisory. Some 10 hours later, a Tropical Cyclone Formation Alert (TCFA) was issued at 060400Z. Following the TCFA and an abrupt change to its westward track, TC07B moved in a general northwestward direction, reaching a peak intensity of 45 kt (23 m/sec). However, increased vertical shear hindered further development and TC07B weakened. After the tropical cyclone moved over land, it weakened, JTWC issued the final warning at 090600Z.



## TROPICAL CYCLONE 08B

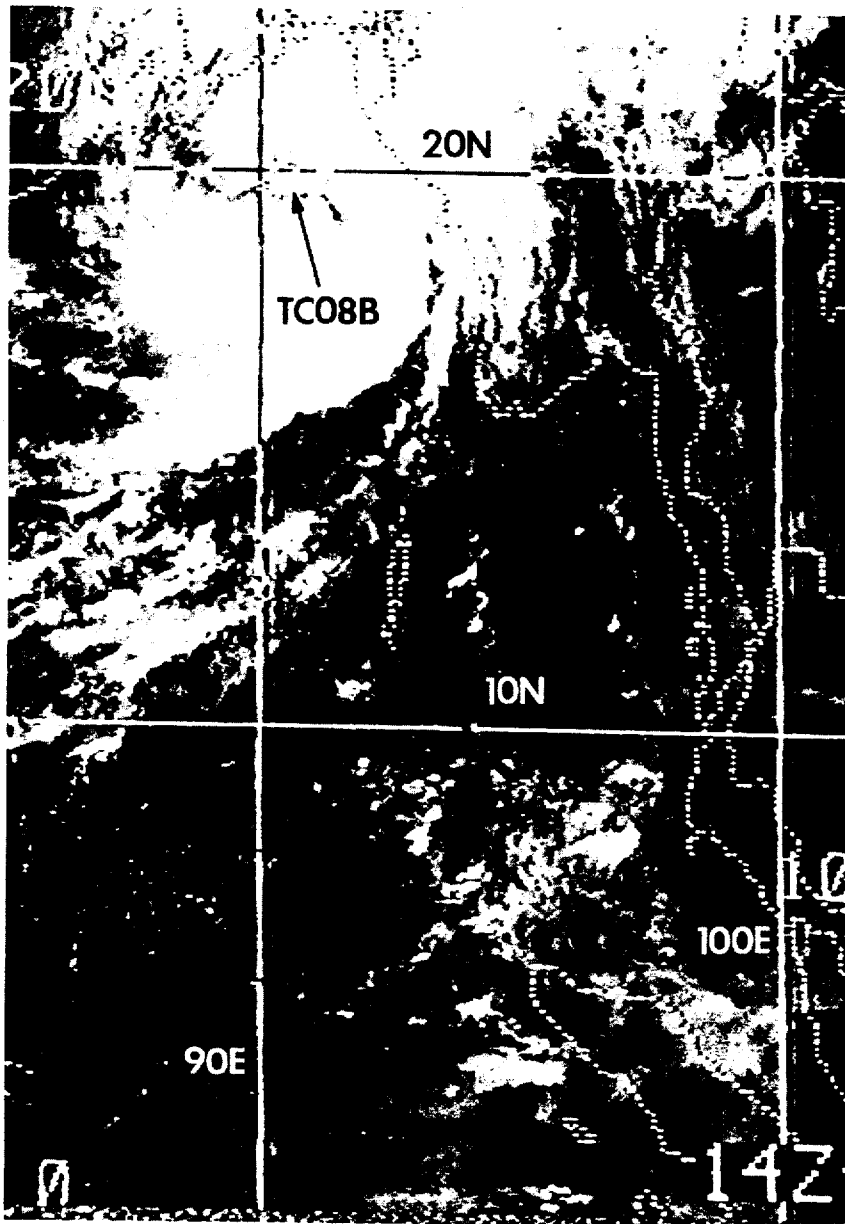
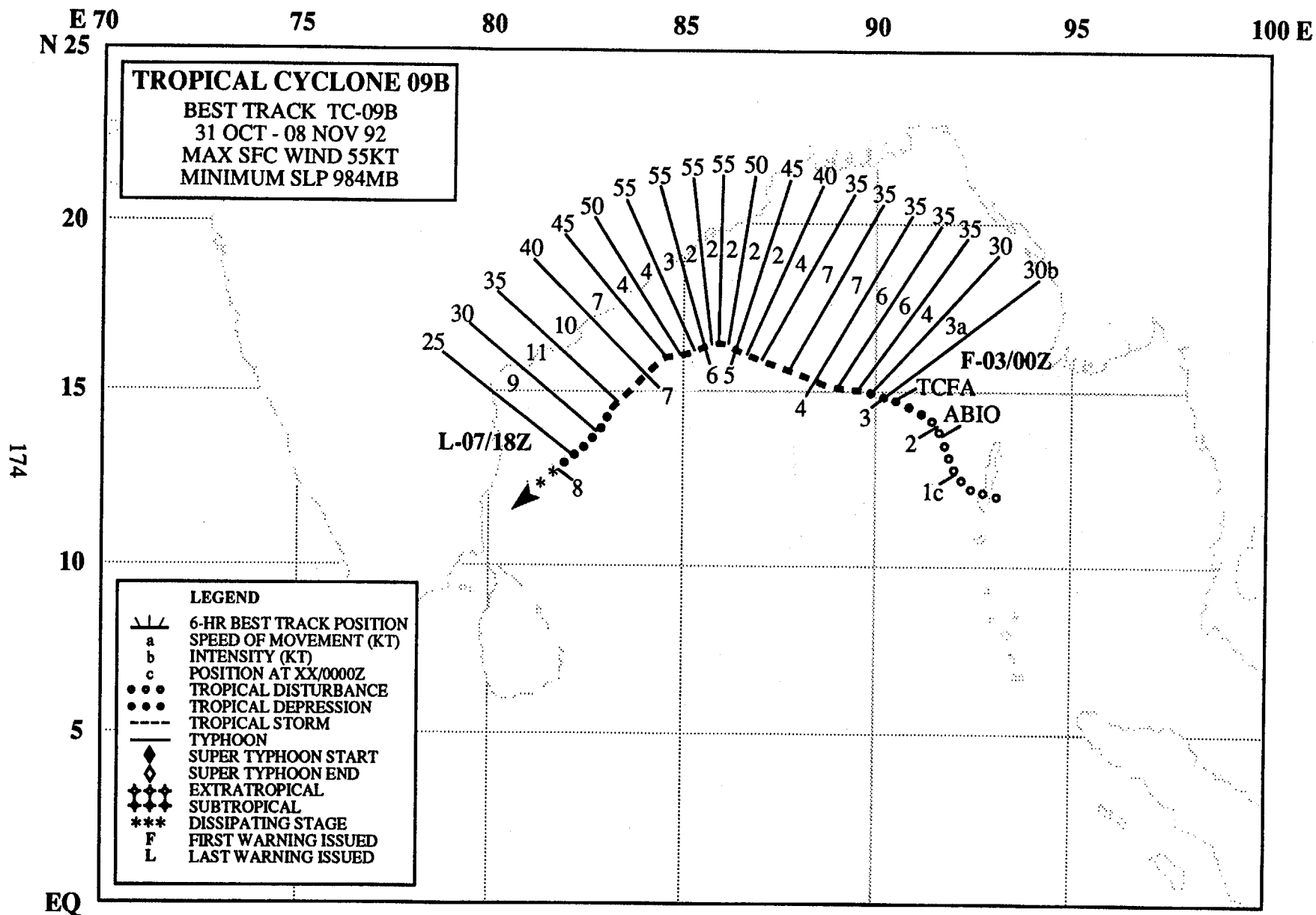


Figure 3-08B-1. Deep convection and heavy rains accompany TC08B as it nears landfall in Bangladesh (210200Z October DMSP infrared digitized mosaic).

Although the tropical disturbance that became TC08B was first mentioned on the 131800Z October Significant Tropical Weather Advisory, noticeable development did not occur until a week later, at which time a Tropical Cyclone Formation Alert was issued by JTWC at 202215Z. The first warning followed at 210600Z when satellite imagery indicated an increase in the amount of cold cloud tops near the cloud system center and improved overall convective organization. TC08B made landfall shortly thereafter on the southern coast of Bangladesh on 21 October. The final warning was issued by JTWC at 211800Z as the weak tropical cyclone dissipated over land.





## TROPICAL CYCLONE 09B

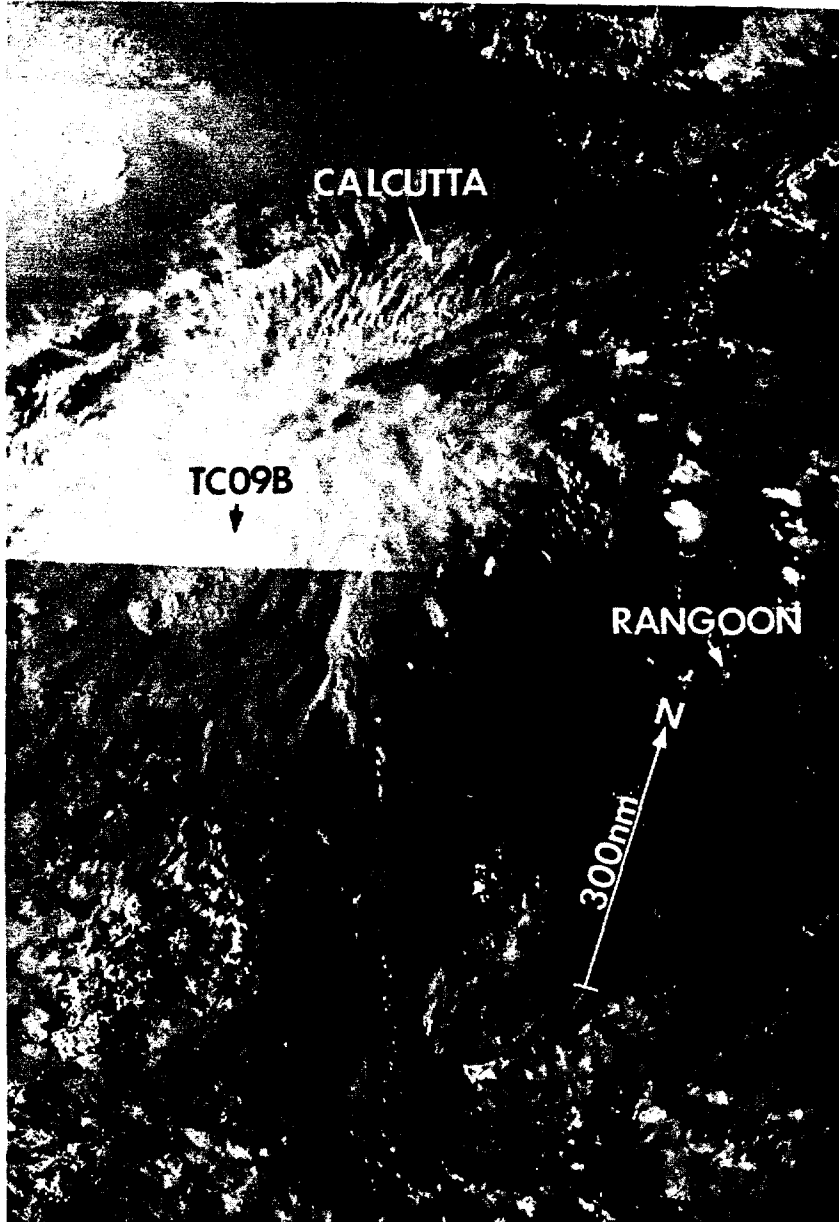


Figure 3-09B-1. TC09B at peak intensity (051048Z November DMSP visual imagery).

The tropical disturbance that became TC09B was first identified on the 011800Z November Significant Tropical Weather Advisory by JTWC as a broad area of convection in the Bay of Bengal. As the tropical disturbance tracked north-northwestward, its convection increased in amount and organization. JTWC issued a Tropical Cyclone Formation Alert at 022100Z, and the first warning at 030000Z. Intensification continued until the tropical cyclone stalled on 5 November. With increasing wind shear aloft over the cyclone, a weakening trend set in on 6 November which continued until TC09B dissipated over water two days later. The final warning was issued by JTWC at 071800Z.

E 65 70 75 80 85 90 95 100 105 110 E  
N 25

# **TROPICAL CYCLONE 10B**

BEST TRACK TC-10B  
06 NOV - 17 NOV 92  
MAX SFC WIND 70KT  
MINIMUM SLP 972MB

## **LEGEND**

- 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◆ SUPER TYPHOON END
- ◆ EXTRATROPICAL
- ◆ SUBTROPICAL
- \*\*\* DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

20

15

10

5

EQ

L-17/18Z

F-11/00Z

TCFA

ABIO

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30

35

35

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35

40

45

50

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## TROPICAL CYCLONE 10B

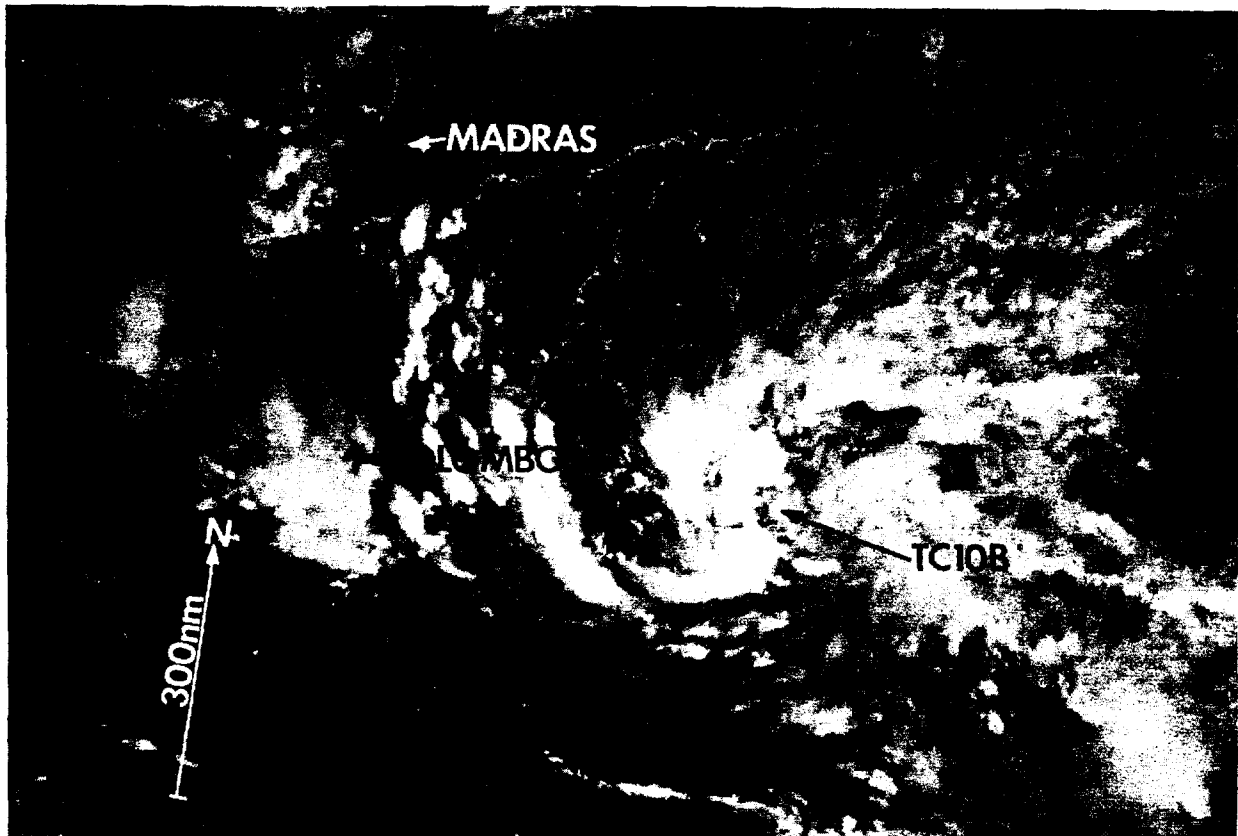


Figure 3-10B-1. TC10B consolidates its convection east of Sri Lanka (101516Z November DMSP moonlight visual imagery).

Forming in the South China Sea on 6 November, the tropical disturbance that became TC10B tracked westward across the Gulf of Thailand, Malay Peninsula, and into the Bay of Bengal on 8 November. Intensification was arrested by strong upper-level winds until the tropical disturbance was halfway across the Bay of Bengal. The cloud system was first mentioned on the 101800Z November Significant Tropical Weather Advisory and was rapidly followed by a Tropical Cyclone Formation Alert at 102200Z, and the first warning at 110000Z. TC10B intensified rapidly, reaching 55 kt (28 m/sec) prior to striking the southern tip of Sri Lanka, and then intensified again to 70 kt (36 m/sec) six hours prior to making landfall on the tip of India. The tropical cyclone tracked northwestward across India, weakened, and moved back offshore into the Arabian Sea where a slight reintensification occurred. As TC10B tracked further north, upper-level westerlies weakened it, and on 17 November it moved over India again. The final warning was issued by JTWC at 171800Z as the cyclonic circulation dissipated over land.

E 70  
N 10

75

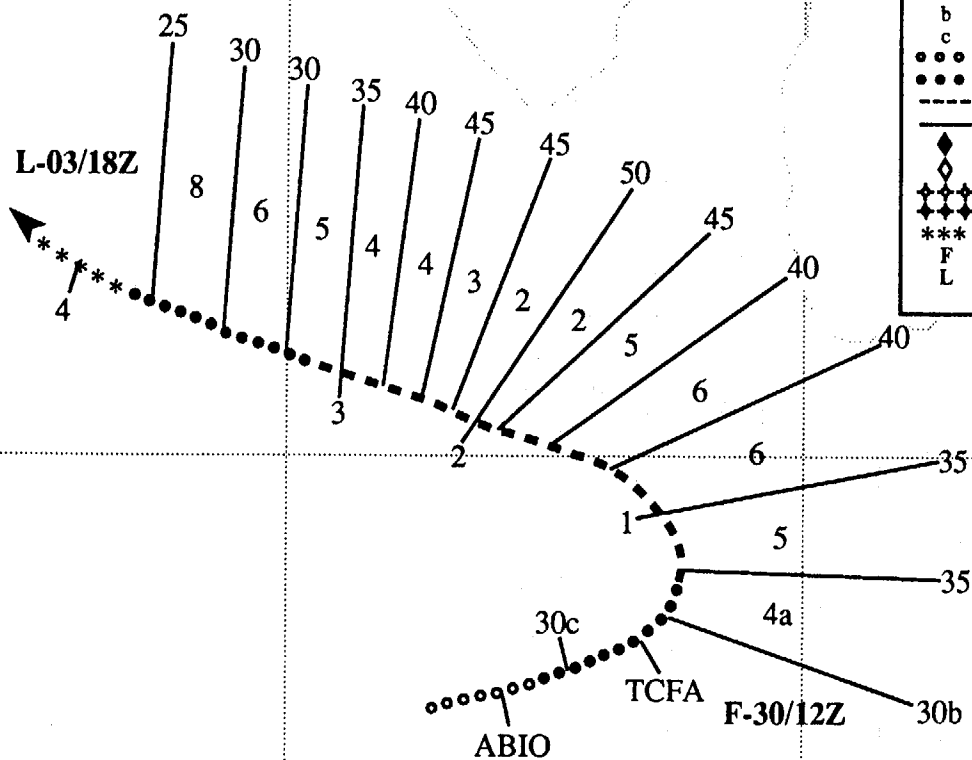
80

85 E

178

5

EQ



**TROPICAL CYCLONE 11A**  
BEST TRACK TC-11A  
29 NOV - 04 DEC 92  
MAX SFC WIND 50KT  
MINIMUM SLP 987MB

## TROPICAL CYCLONE 11A

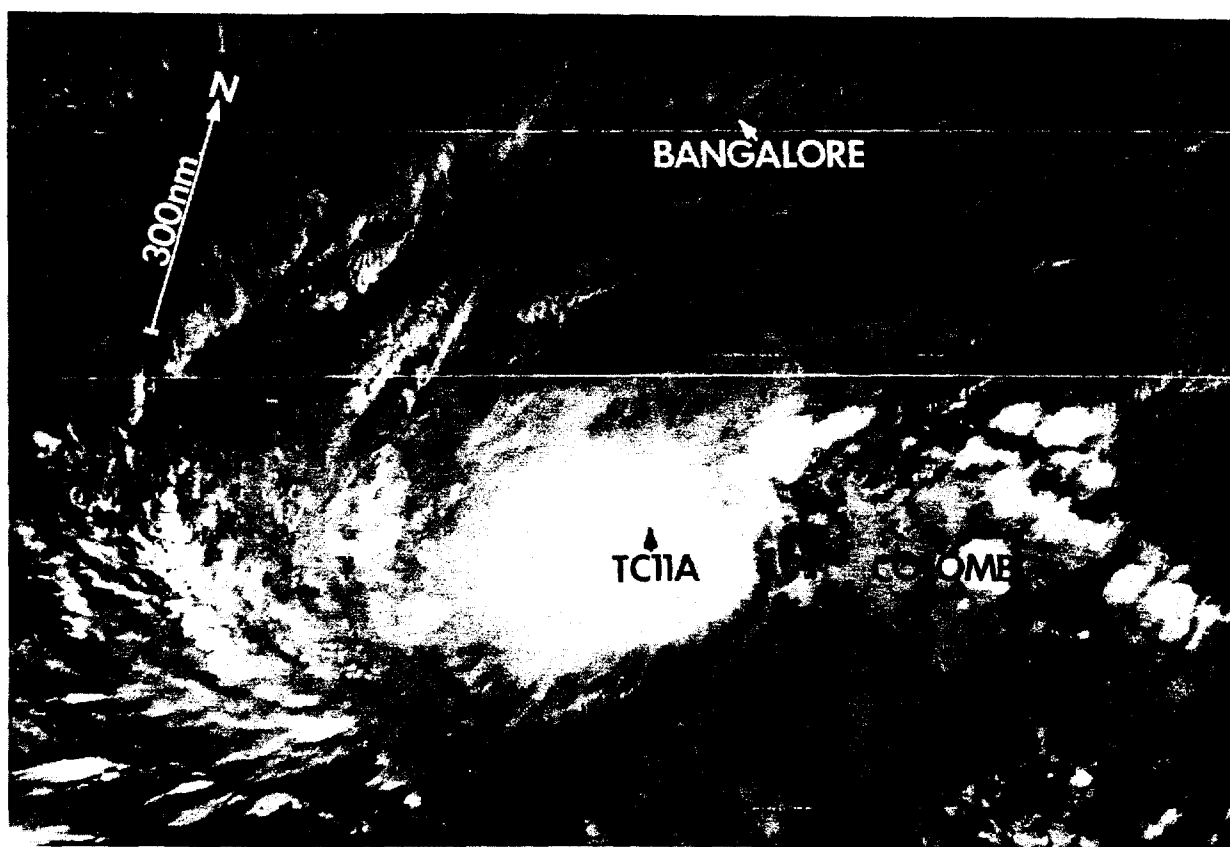
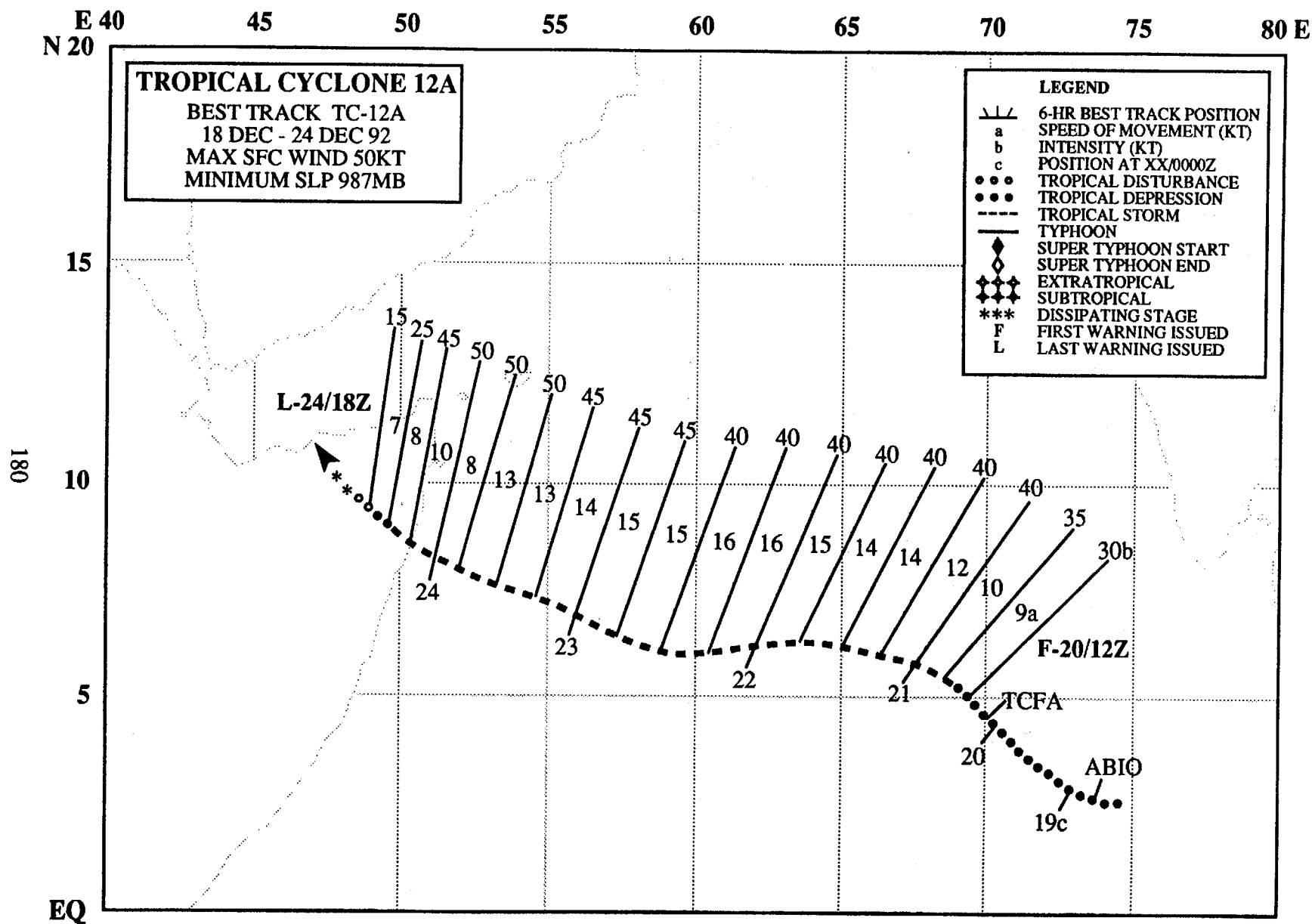


Figure 3-11A-1. TC11A at peak intensity (011559Z December infrared imagery).

The third Arabian Sea tropical cyclone of 1992 developed in the near equatorial trough southwest of Sri Lanka. The tropical disturbance that eventually became TC11A was first mentioned by JTWC on the 291800Z December Significant Tropical Weather Advisory. Increasing convective curvature prompted JTWC to issue a Tropical Cyclone Formation Alert at 300800Z followed by the first warning at 301200Z. As TC11A intensified, it turned to the northwest under the steering of the mid-level subtropical ridge. The tropical cyclone reached a maximum intensity of 50 kt (26 m/sec) briefly at 020000Z before the onset of increasing upper-level wind shear. TC11A gradually weakened until it dissipated over water on 3 December. The final warning was issued by JTWC at 031800Z.



## TROPICAL CYCLONE 12A

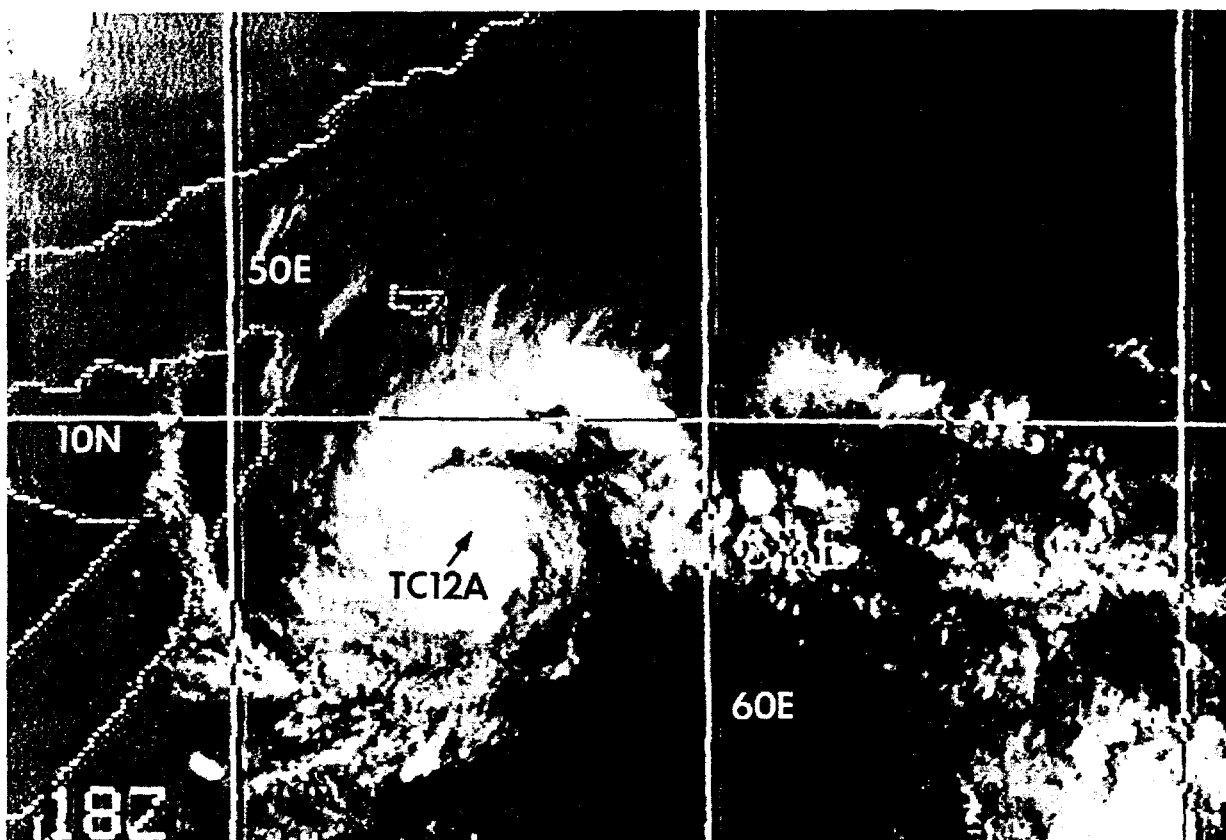


Figure 3-12A-1. At peak intensity, TC12A approaches the coast of Somalia (230500Z December DMS infrared imagery).

Tropical cyclone 12A was the fourth cyclone in the Arabian Sea and the twelfth cyclone in the North Indian Ocean in 1992. For JTWC, this set an all-time record for the number of significant North Indian Ocean tropical cyclones. The previous record was eight significant tropical cyclones in 1987. The tropical disturbance that became TC12A formed in the Maldives in the near equatorial trough and was initially mentioned by JTWC on the 181800Z December Significant Tropical Weather Advisory. A Tropical Cyclone Formation Alert was issued at 200400Z followed by the first warning at 201200Z. TC12A tracked quickly westward across the central Arabian Sea towards the coast of Somalia. Accurate warnings allowed ships supporting Operation RESTORE HOPE to transit the Arabian Sea without any damage, diversions or delays. Warnings were sent out with expanded prognostic reasoning messages to keep operational commanders and their weather personnel informed on JTWC's rationale for the tropical cyclone's movement and intensity forecasts. Reaching a peak intensity of 50 kt (26 m/sec) just prior to landfall, TC12A weakened rapidly after making landfall in Somalia, bringing much needed rain to a dry country. JTWC issued the final warning at 241800Z as TC12A dissipated over land.



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